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Materials for Airplane Construction*

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THERE are no materials used in airplane construction which are not adaptable to other fields of engineering. The aeronautical industry has been willing to pay a higher price for low specific density. This has led to greater selectivity among the common materials of construction and stimulated the development of new materials which are more adaptable to light-weight structures.

The stress-strain relationship developed by tensile loading, Plate 1, is a basic property of the material and indicates its suitability for engineering structures. The specific density curves show the relationship between bars of equal weight and illustrate the general conclusions which have been reported in several engineering papers that steel of high tensile strength is superior for airplane elements subjected to tensile loads only and that low specific gravity alloys are comparable to steel for structural members subjected to flexural loads where there is no restriction on dimensions or form. The correctness of these conclusions has been demonstrated by static load tests on full scale designs manufactured from steel and aluminum alloys.

The majority of failures of aircraft parts are caused by fatigue. It is seldom that the ultimate strength of the material is exceeded by a single application or the creep strength by a continuous application of load. The resistance to repeated stresses is indicated by stress-cycle diagrams, Plate 1. These were obtained on small, highly polished specimens tested as rotating beams. The fatigue limit or stress at which the material will vibrate indefinitely is apparently a basic property of the material. Surface condition, notches, scratches, threads, and other external or internal irregularities lower the fatigue strength, Table 2. The reduction increases with the size of the defect in relation to the size of the part and the localized concentration of stress which varies with the radius at the root of the notch or edge of the hole. The lack of information on the distribution and range of the stresses and the effect of instability and restraint precludes the direct application of these data to the stress analysis of structural parts subject to vibration. The more direct method of attack is to vibrate the built-up assemblies simulating the loads in service. It is apparent from the failures in service of both corrosion-resistant steel and aluminum alloys that the basic fatigue limit is of secondary importance to the correct combination of structural rigidity and plasticity to control the amplitude and frequency of vibration. The vibration test for fuel and oil tanks, 25 hours at a $^1/_{32}$ inch amplitude at a frequency which is a percentage of the revolutions of the engine, unquestionably improved tank design and the same principles of testing are being extended to wing and fuselage.

Specific density is of primary importance but the choice of a material is greatly influenced by such factors as availability in economical sizes and shapes, ease of

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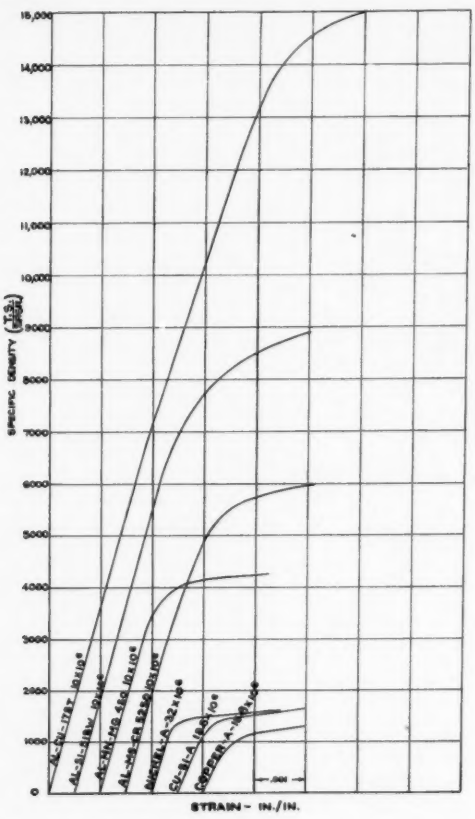
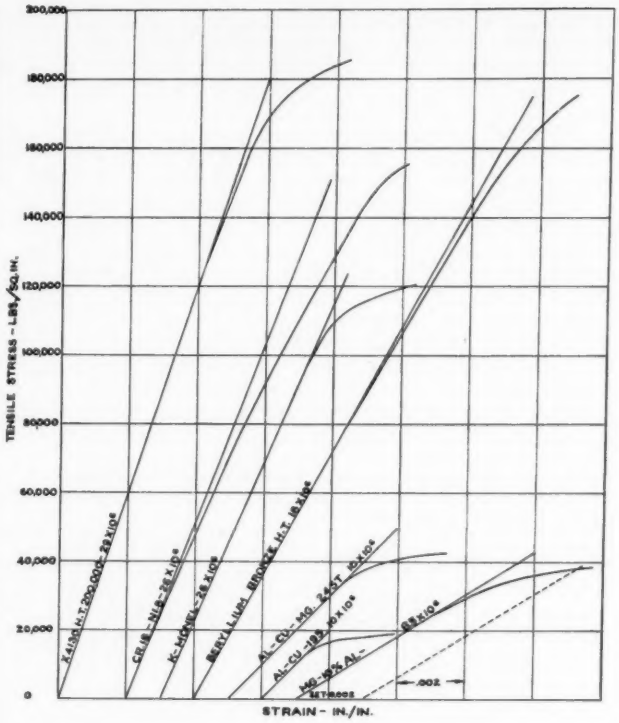




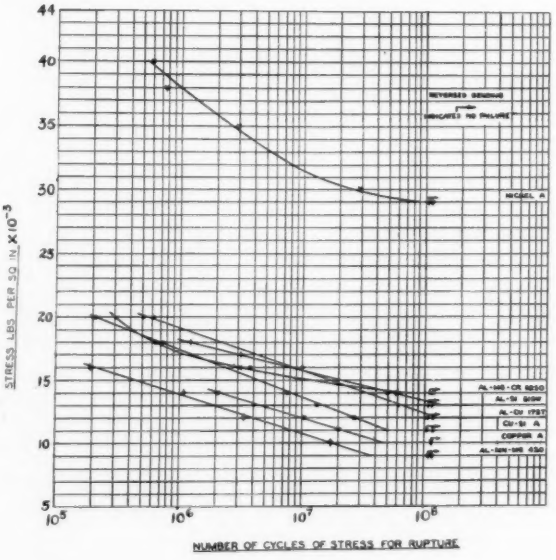


PLATE 1a—TUBING.[1]

Material	Specific Gravity	Ni	Cu	Al	Mg	Si	Mg	Tensile Strength Lbs. per Sq. In.	Yield Strength Lbs. per Set 0.002 In.	Elongation 2 In. Per-cent
Nickel, Annealed	8.82	99.9	0.06	.....	..	...	...	65,000	14,000	48
Copper-Silicon Annealed	8.54	...	95.71	.....	..	3.0	1.0	52,000	14,500	55
Copper, Annealed	8.32	...	99.96				...	33,000	10,900[2]	55
Al-Cu-Mg (17ST)	2.79	...	3.99	Rem.	0.4	0.26	0.5	62,000	41,000	25
Al-Mg-Cr (52SO)	2.67	...	....	"	2.2	...	0.1	29,000	14,000	25
Al-Si-Mg (51SW)	2.69	...	0.08	"	0.4	0.94	...	39,000	24,000	28
Al-Mu-Mg (4SO)	2.72	...	0.11	"	1.2	0.24	1.1	27,000	11,000	23

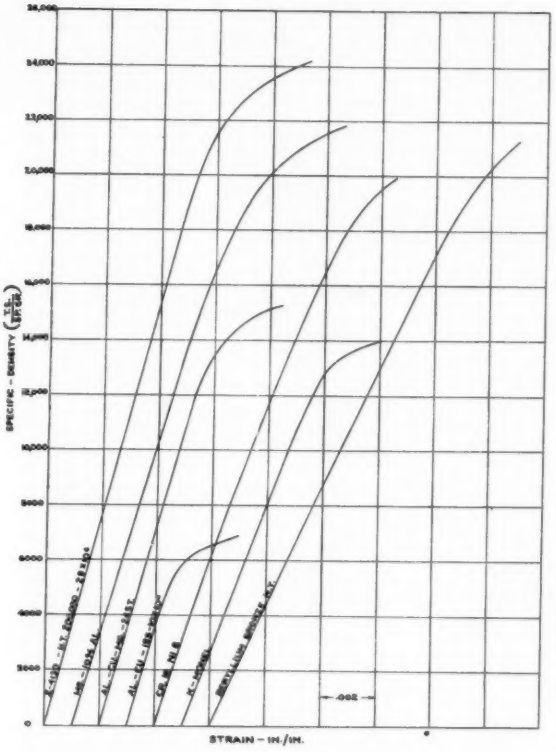
[1] 3/8 inch O.D. t = 0.035, 0.050, and 0.065.
[2] Set = 0.005 inch.

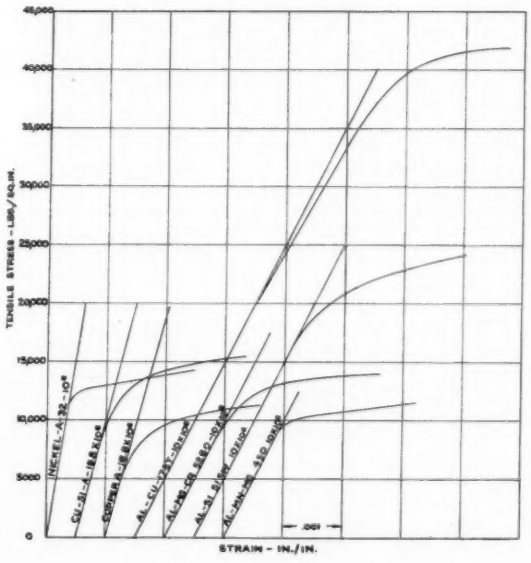
fabrication and serviceability which includes resistance to abrasion and damage from rough handling, reactions between dissimilar materials under corroding media, and facility in making repairs.

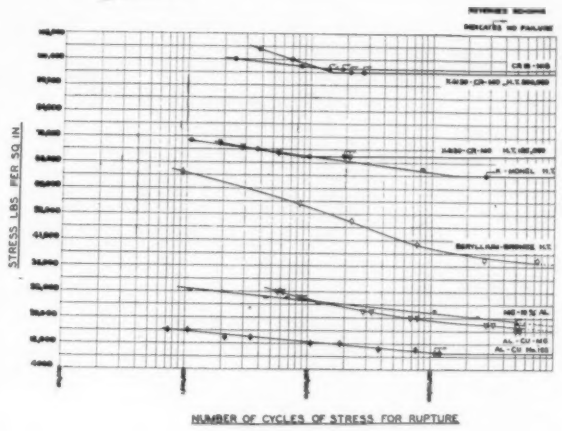
ALUMINUM ALLOYS

The importance of aluminum and aluminum alloys in aircraft construction is demonstrated by their usage. The structural weight of several successful military and transport airplanes is divided into

Aluminum Alloys (non-heat-treatable)	5	to 8	percent
Aluminum Alloys (heat-treated)	70	to 80	percent
Steel, Low Alloy	14	to 18	percent
Nickel Alloys or Steel, corrosion-resistant	2	to 3	percent
Copper Alloys	0.3	to 0.5	percent
Miscellaneous materials	1	to 2	percent







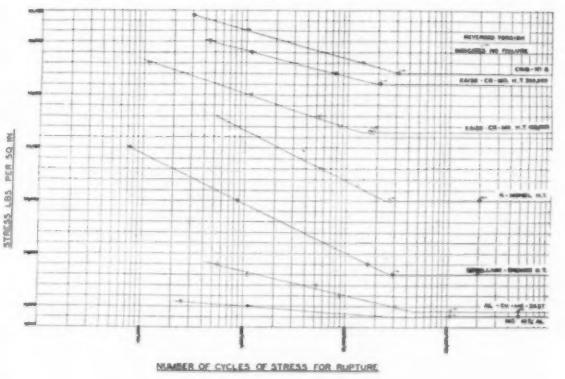


PLATE 1b.

Material	Specific Gravity	Chemical Composition C	Mg	Cr	Ni	Mo	Fe	Cu	Al	Mg	Mechanical Properties Tensile Strength Lbs. per Sq. In.	Yield Strength	Elong. 2 In. Per-cent	Brinell Hardness
X-4130	7.93	0.31	0.64	0.69		0.22	98				127,000	120,000	20	280
X-4130	7.93	0.31	0.64	0.69		0.22	98				200,000	186,000	17	434
Chromium														
Nickel														
St.18:8	7.87	0.05	0.60	17.9	8.9		72				204,000	155,000	11	425
K-Monel	8.58	0.16	0.67		63			1.9	30.3	3.6	146,000	124,000	20	293
Beryllium						Be								
Bronze	8.22					2.3			97.7		200,000	172,000	1	415
Al-Cu-Mg			Si											
24ST	2.76	0.2.	0.44					0.13	4.0	95	67,000	42,000	24	118
Al-Cu			Si											
195	2.77	0.7						0.5	4.3	94	36,000	19,000	3	70
Mg-90						Zn								
Al-10	1.80		0.12			0.4			10	89	47,000	38,000	6	73

Data from Wright Field using same test equipment and procedure.

Aluminum alloys are used in practically all forms in which metal can be worked—castings, extrusions, forgings, pressings, sheets, bars, wires, and tubing. The selection of the form is based on the specific application and the economy of fabrication. For example, equally satisfactory fittings are made from castings, forgings, extrusions, or stampings.

The division into heat-treated and non-heat-treated alloys is a natural one. The non-heat-treatable alloys, 99 percent aluminum (2S), 1.5 manganese (3S), manganese-magnesium (4S), and magnesium-chromium (52S), in the form of sheets are suitable for cowling, fairing, wing tips, the leading edges of small airplanes, flooring, tanks, and miscellaneous low stressed parts, and in the form of tubing for such parts as fuel and oil lines, air speed indicator tubes, and conduit. The 99 percent aluminum is soft and ductile, which is desirable from the fabricator's standpoint, but less so to the user on account of the ease with which the material is bent and abraded, and the low bearing strength at

TABLE 1

ALUMINUM BASE ALLOYS

CLASSIFICATION	SPECIFICATIONS: FEDERAL	U.S. ARMY OR AIR CORPS	U.S. NAVY	S.A.E.	MFRS NO.	CHEMICAL COMPOSITION: ALUMINUM	COPPER	MAGNESIUM	MANGANESE	IRON	SILICON	NICKEL	ZINC	CHROMIUM	TEMPER	MECHANICAL PROPERTIES: ULTIMATE STRENGTH P.S.I.	YIELD STRENGTH P.S.I.	ELONGATION %	COMPRESSIVE STRENGTH P.S.I.	SHEAR STRENGTH P.S.I.	BRINELL HARDNESS 500 KG.	FATIGUE REVERSING 500 X 10⁶ CYCLES
SHEET & PLATE	QQ-A-561	57-151-1	47A2	25	2S	99.0									1/2HARD	16,000	14,000	3.0				
	QQ-A-359		47A4	29	3S	97.0	0.20		1.0-1.5	0.70	0.60				1/2HARD	19,500	17,000	3.0				
				30	4S	96.0	0.20	1.09-1.4	0.9-1.4						ANNEALED	26,000	10,000	10.0				
	QQ-A-353		47A3	26	17S	92.0	3.5-4.5	0.2-0.75	0.4-1.0						H.T.	55,000	32,000	15.0				
		57-152-2	47A6		17S ALCLAD	92.0	3.5-4.5	0.2-0.75	0.4-1.0						H.T.	50,000	27,000	13.0				
		57-152-6	47A10	24	24S	92.0	3.8-4.9	1.2-1.75	0.3-0.9						H.T.	62,000	40,000	12.0				
		11067	47A8		24S ALCLAD	92.0	3.8-4.9	1.2-1.75	0.3-0.9						H.T.	56,000	37,000	12.0				
				28	51S	97.0		0.6			1.0			0.25	HT&AGED	45,000	35,000	8.0				
	QQ-A-318	11072	47A11		52S	REM.	0.10	2.2-2.8	0.10	FE+SI=0.45 MAX.			0.03	0.15-0.35	1/2HARD	34,000	24,000	4.0				
	QQ-A-354		47A12		53S	REM.	0.10	1.1-1.4		0.35	(1)		0.03	0.2-0.3	HT&AGED	35,000	28,000	8.0				
					17S-T35	3.9 CORE WITH ALUMINUM-ZINC COATING																
BAR, ROD, WIRE & SHAPES	QQ-A-411		46A3	25	2S										1/2HARD	16,000	14,000	20.0	17,000	11,000 [A]	32	7,000 [A]
	QQ-A-356		46A6	29	3S										1/2HARD	19,500	18,000	20.0	19,500	14,000 [A]	40	9,500
	QQ-A-351		46A4	26	17S										H.T.	55,000	30,000	18.0	55,000	30,000	100	13,000
		57-152-5	46A9	24	24S										H.T.	62,000	40,000	16.0	65,000	35,000	105	14,000
			46A11		52S										1/2HARD	34,000	29,000	10.0		21,000 [A]	67	19,000 [A]
	QQA-731		46A10		53S										HT&AGED	32,000	25,000	16.0		24,000 [A]	60	11,000 [A]
TUBING	WW-T-783		44T19	25	2S										1/2HARD	16,000	14,000	9.0				
	WW-T-788		44T20	29	3S										1/2HARD	19,500						
		11059		20	4S										1/2HARD	32,000		10.0				
	WW-T-786		44T21	26	17S										H.T.	55,000	40,000	16.0				
		10235	44T28	24	24S										H.T.	62,000	42,000	16.0				
		57-187-3	44T32		52S										1/2HARD	34,000	24,000	5.0				
			44T30		53S										HT&AGED	35,000	28,000	16.0				
FLEXIBLE TUBING		10236	49T12		3S																	
		10236	49T12		52S																	
FORGINGS	QQ-A-367	57-153	M277		14S	REM.	3.9-5.0	0.2-0.75	0.4-1.2	1.0	0.5-1.2				H.T.	65,000	50,000	10.0	70,000	45,000 [A]	130	15,000
	QQ-A-367	57-153	46A7	26	17S	92.0	3.5-4.5	0.2-0.75	0.4-1.0	1.0	0.75			0-0.25	H.T.	55,000	30,000	16.0	55,000	36,000	90	13,000
	QQ-A-367	57-153			18S	REM.	3.5-4.5	0.45-0.9	0.20	1.0	0.90	1.7-2.3			H.T.	55,000	35,000	10.0	45,000		90	
	QQ-A-367	57-153	46A7	27	25S	92.0	3.9-5.0	0.03	0.4-1.2	1.0	0.5-1.2				H.T.	55,000	30,000	16.0	55,000	35,000 [A]	90	14,000
	QQ-A-367	57-153			32S	REM.	0.5-1.3	0.8-1.3	0.20	1.0	11.5-13.5	0.5-1.3		TI-0.20	H.T.	52,000	40,000	5.0	50,000	38,000 [A]	110	14,000
	QQ-A-367	57-153	46A7		A51S	96.5	0.25	0.45-0.80	0.20	1.0	0.6-1.2			0.15-0.35	H.T.	43,000	34,000	12.0	45,000	23,000	90	10,500 [A]
					X73S	REM.	0.90	0.75-1.00		1.0	0.7		4.5-6.0		H.T.	48,000	38,000	12.0		34,000	95	15,500
RIVETS & RIVET WIRE		25526	43R5		A17S	REM.	2.0-3.0	0.2-0.5	0.20	1.0	0.80									25,000		
WELDING ROD	QQ-R-571		46R1		43S	92.5	0.60	0.02	0.20	1.00	4.5-6.0		0.20									
	QQ-R-571		46R1		99%	99.0																
WIRE-METAL SPRAY		10285			99%	99.0																
SAND CASTINGS		11311	46A1	35	43	93.0	0.10	0.05	0.07	0.80	4.5-6.0				AS CAST	17,000	7,000	3.0	25,000	14,000 [A]	40	5,000
		11312			108	REM.	3.5-4.5	0.03	0.30	1.0	3.5				AS CAST	19,000		1.0	62,000	20,000 [A]	55	8,500 [A]
		57-72-1	M212	39	142	90.0	3.8-4.5	1.2-1.8		0.80	0.50	1.7-2.3			H.T.	32,000	20,000		77,000	32,000 [A]	100	8,000
		57-72-5	46A1	38	195	92.0	4.0-5.0	0.03	0.30	1.20	1.20				H.T.	32,000	18,000	3.0	50,000	30,000 [A]	80	9,000
		11310			212	REM.	7.0-8.5		0.30	1.40	1.0-1.5				AS CAST	19,000			64,000	20,000 [A]	65	7,500 [A]
		57-72-4	46A1		214	94.0	0.05	3.5-4.5	0.60	0.50	0.40				AS CAST	22,000	10,000	6.0	45,000	18,000	50	8,000
		11309	M186	324	220	88.0	0.20	9.5-11.0		0.30	0.20				H.T.	42,000	22,000	12.0	72,000	33,000 [A]	75	7,500
		11307	M212	322	355	91.0	1.0-1.5	0.4-0.6	0.30	0.50	4.5-5.5				H.T.	32,000	20,000	1.0	65,000	30,000 [A]	92	7,500
		11308	46A1	323	356	REM.	0.20	0.2-0.4	0.03	0.50	6.5-7.5		0.03	TI-0.20	H.T.	30,000	20,000	3.0	50,000	22,000	90	8,000
DIE CASTINGS		57-93-1		307	85	REM.	3.5-4.5	0.10	0.30	2.25	4.5-5.5	0.50	0.75		AS CAST	32,000	18,000	2.0			60	17,000 [A]
		57-93-1		305	13	REM.	0.60	0.10	0.30	2.00	11-13	0.50	0.75		AS CAST	33,000	16,000	1.5			80	15,000 [A]
MAGNESIUM BASE ALLOYS																						
SHEET			M111		ZM-AM35		0.05	REM.	1.20		0.30				ANNEALED	35,000	15,000	12.0			48	
BARS & FORGINGS			M126		ZK1-AMC575	5.8-7.2		REM.	0.15		0.50		1.5		EXTRUDED	40,000	26,000	12.0	64,000	20,500 [A]	55	14,000
SAND CASTINGS		57-74-1			ZG5-AMC102	9-11		8.9-10	0.10		0.50		0.30		HT	30,000	18,000	1.0	54,000	21,000 [A]	65	9,000 [A]
		57-74-1	M112		ZG1-AM263	5.3-6.7	0.05	REM.	0.15		0.50	0.03	2.5-3.5		HT&AGED	32,000	16,000	2.0	50,000	18,000 [A]	62	10,000 [A]
					AM403		0.05		1.20		0.30	0.03			AS CAST	12,000		3.0				

(1) NOT LESS THAN 45% OR MORE THAN 65% OF MAGNESIUM CONTENT.
(A) ALUMINUM CO. OF AMERICA (D) DOW CHEMICAL CO.

IRON BASE ALLOYS

CLASSIFICATION	SPECIFICATIONS: FEDERAL	U.S. ARMY OR AIR CORPS	U.S. NAVY	S.A.E.	MFGR. NUMBER	CHEMICAL COMPOSITION: IRON	CARBON	MANGANESE	SILICON	CHROMIUM	NICKEL	MOLYBDENUM	MISC.	TEMPER	MECHANICAL PROPERTIES: ULTIMATE STRENGTH P.S.I.	YIELD STRENGTH P.S.I.	ELONGATION %	COMPRESSIVE STRENGTH P.S.I.	SHEAR STRENGTH P.S.I.	BRINELL HARDNESS 3000 Kg.	FATIGUE REVERSING 500 X 10⁶ CYCLES
SHEET AND		57-136-8	47S14	X-4130		REM.	.25-.35	.40-.60		.80-1.10		.15-.25		NORM.	90,000	70,000	10				
STRIP		57-136-9	47S19			"	0.07	1.50	1.50	17.0	8.0	Cb+TA=10XC OR Ti=5.5XC		ANN.	100,000 (1)	35,000	40				
		11068	47S21			"	0.12	0.70	0.70	17.0	7.0			C.R.	185,000	140,000	3				
BAR, ROD AND		57-107-9	46S23	4130 X4130		"	.25-.35	.40-.80		.50-1.10		.15-.25		H.T.	125,000	100,000	18	125,000	75,000	265	70,000
BILLETS		57-107-28	46S30			"	.38-.45	.40-.70	0.30	1.40-1.80		.30-.50	Al 0.95-1.35		135,000	100,000	18.0	135,000	80,000	280	80,000 (2)
		10079	46S18			"	0.20	1.50	0.70	17.0-20.	7.0-10.0		Cu 0.50	CR	125,000	100,000	12	125,000	70,000	200	68,000
		10083	46S23	4140		"	.35-.45	.60-.90		.80-1.10		.15-.25		H.T.	125,000	100,000	18	125,000	75,000	265	
		11062	46S28	X-4340		"	.35-.45	.50-.80		.60-.90	1.5-2.0	.20-.30		H.T.	150,000	130,000	15	150,000	90,000	315	77,000
TUBING		57-180-2	44T18	X4130		"	.25-.35	.50-.80		.50-.80		.15-.25		NORM.	95,000	75,000	10.0	95,000			41,000
		57-180-3	44T25			"	0.07	1.50	1.50	17.0	7.0	Cb=10XC OR Ti=5.5XC		ANN.	80,000	30,000	40.0				24,000
		57-180-4	44T26			"	0.07	0.20-0.7	1.50	17.0	8.0	Cb=10XC OR Ti=5.5XC		WELDED							
CASTINGS	QQ-S-681	57-64-1				"	0.45	1.25-1.50	.25-.50	.50-1.00		.15-.35		H.T.	100,000	70,000	17.0	100 00	65,000		48,000

(1) MAXIMUM (2) NITRIDED

COPPER BASE ALLOYS

CLASSIFICATION	SPECIFICATIONS					CHEMICAL COMPOSITION										TEMPER	MECHANICAL PROPERTIES						
	FEDERAL	U S ARMY OR AIR CORPS	U S NAVY	S A E	TYPE	COPPER	LEAD	TIN	IRON	ZINC	MANGANESE	SILICON	PHOSPHORUS	NICKEL	ALUMINUM		ULTIMATE STRENGTH P S I	YIELD STRENGTH P S I	ELONGATION %	COMPRESSIVE STRENGTH P S I	SHEAR STRENGTH P S I	BRINELL HARDNESS	REDUCE ON REV. BEND. 500 LBS TO 0.1 IN
ROD, BAR, SHEET, STRIPS & SHAPES		11070			BERYLLIUM COPPER	REM.			0.25					0.50	2.0-2.25	QUENCHED	95,000	75,000	7	100,000		B-100	80,000
		57-160		79	LOW BRASS	79-81	0.15		0.06	REM						ANN	40,000						
		57-162-1	46-B-26		SPEC NAVAL BRASS	59-62	0.30	0.50-1.50	0.10	REM.							67,000	45,000	22	70,000	45,000	B-75	21,000
	QQ-B-721		46-B-15		MANGANESE BRONZE	57-60	0.20	0.50-1.50	0.8-2.0	REM	0.50				0.25	1/2H	72,000	36,000	20	75,000		B-75	17,000
	QQ-B-666		46-B-17	70	ALUMINUM BRONZE	84-93			4.0						7.0-10.0		80,000	40,000	15	80,000	50,000	B-100	28,000
	QQ-B-611		47-B-2	70	HIGH BRASS	64.5-67.5	0.30		0.05	REM						1/2H	52,500	20,000	15	55,000		B-70	15,000
	QQ-C-501		47-C-2	71	COPPER	99.90											37,000		25				
	QQ-B-636			73	NAVAL BRASS	59-62	0.20	0.50-1.50	0.10	REM						1/2H	60,000	25,000	15	80,000		B-75	
	QQ-B-746		46-B-14	77	PHOSPHOR BRONZE	94.0	0.10	3.50	0.05	0.30			0.05-0.50			1/2H	80,000	60,000	12			B-80	27,000
	QQ-B-611			88	COMMERCIAL BRASS	58.5-61.5	1.5-2.5		0.15							ANN	45,000	18,000	25				18,000
TUBING		57-192-1	44-T-23		COPPER-SILICON BRONZE	REM			0.25		0.85-1.35	2.85-3.55				ANN	50,000		35				
	WW-T-791		44-T-15	74	LOW BRASS	83-86	0.06		0.05	REM						ANN	38,000		25				
	WW-T-791		44-T-15	74	HIGH BRASS	65-68	0.80		0.07	REM													
	WW-T-799			75	COPPER	99.90																	
WIRE	QQ-W-341	57-222-1	22-W-9	83	SOFT COPPER											ANN	36,000		35				
	QQ-W-321			80	BRASS	64-69			0.06	REM							56,000						
	QQ-W-321			80	BRASS	69-74	0.075		0.06	REM						SPRING	120,000						
	QQ-W-401		22-W-5	81	PHOSPHOR BRONZE	94.0	0.20	3.50	0.10	0.02			0.05-0.5			SPRING	130,000	70,000	3.5				
CASTINGS		11076			ALUMINUM BRONZE	78.0		0.20	5.0		5.0			5.0	10.5-12.0	H.T.	85,000	50,000	3.	105,000		200 B-95	
	QQ-C-516		46-B-28		COPPER-SILICON BRONZE	REM		0.20	2.50	5.0	1.5	1.0-5.0					45,000		15				
		11306			COPPER-LEAD BRONZE	70-74	26-30	0.30	0.10	0.10			0.05	0.50									
	QQ-B-691	11306	46-B-23	40	RED BRASS	84-86	4.0-6.0	4.0-6.0	0.25	4.0-6.0			0.05	0.75			27,000	14,000	15.	30,000		45	
	QQ-B-621		46-B-11	41	NAVAL BRASS	60-67	1.0-3.0	0.5-1.5	0.0-0.75	REM.					0.0-0.50		30,000		15.				
	QQ-B-726		49-B-3	43	MANGANESE BRONZE	55-60	0.40	1.50	0.40-2.0	38-42	3.50				1.50		65,000	25,000	20.	85,000	40,000	B-90	17,000
	QQ-B-691	11306	46-B-5	62	GUN METAL	86-89	0.0-0.3	7.5-11.0	0.10	1.5-4.5			0.05	0.75			40,000	18,000	20	44,000		80	
	QQ-B-691	11306	46-B-5	64	PHOSPHOR BRONZE	82-85	7.0-9.0	7.0-9.0	0.15	0.0-0.25			0.3-0.60	1.0			25,000		8.	40,000		55	

NICKEL BASE ALLOYS

CLASSIFICATION	SPECIFICATIONS					CHEMICAL COMPOSITION								TEMPER	MECHANICAL PROPERTIES						
	FEDERAL	U.S. ARMY OR AIR CORPS	U S NAVY	S A E	MFGS NUMBER	NICKEL	COPPER	IRON	CHROMIUM	MANGANESE	CARBON	SILICON	ALUMINUM		ULTIMATE STRENGTH P S I	YIELD STRENGTH P S I	ELONGATION %	COMPRESSIVE STRENGTH P S I	SHEAR STRENGTH P S I	BRINELL HARDNESS 3000 Kg	REVERSE BEND TO BREAK 500 LBS 0.1 IN.
ROD, BAR, SHEET		57-174	47N1		INCONEL	75.0	0.5	9.0	12-15	1.00	0.15	0.50		ANN	80,000	30,000	35.0	75,000		110	
STRIP, SHAPES	QQ-C-541		46M7		MONEL	63-70	REM	2.50		2.0	0.30	0.50	0.50	CR	90,000	70,000	17			180	
& TUBING			M-253		K MONEL	63-70	*	2.00		1.0	0.25	0.50	2.0-4.0	H.T	145,000	110,000	15			290	64,000
CASTINGS	QQ-C-551		46M1			60.0	23.0	3.5		3.5			0.5		65,000	32,500	25				
WIRE SPRING		57-174													175,000						
	QQ-C-541														160,000						

rivet and bolt holes which has caused the rupture of cowling in flight. Consequently, the alloys have replaced it in high performance airplanes. With these alloys the ductility decreases and the ratio of yield strength to ultimate strength increases rapidly with cold work. For soft, annealed alloys the ratio varies from 0.3 to 0.5, and for full hard material rises to 0.75 and 0.9. The higher value applies to the magnesium-chromium alloy (52S) and is an indication of the greater difficulty encountered in severe cold forming such as spinning and deep drawing. Spot welds in this alloy have high strength and corrosion resistance and spot welded fuel tanks have given excellent service. The corrosion resistance is equivalent to the aluminum coated materials, but paint adhesion is not so good as with other alloys. The manganese-magnesium (4S) alloy has better deep forming properties and has been used to a limited extent for ring cowls. In the form of tubing it has been used for fuel and oil lines, but has been replaced by the magnesium-chromium alloy in the interests of standardization. The aluminum-manganese alloy (3S) has the widest application of any of the non-heat-treatable alloys on account of its availability, lower cost, and weldability. The non-heat-treatable alloys are less costly and more economical to fabricate since no heat treatment and straightening are required after forming. The design of the tools and the character of the equipment used by the fabricator

TABLE 2
Effect on Fatigue Limit of a Circular Groove
(60° included angle; 0.005 inch radius at bottom; ratio $\frac{\text{dia. specimen}}{\text{depth groove}} = 10$)

Material	Tensile Strength Lbs. per Sq.In.	Elong. 2 In. Percent	Brinell Hardness	Fatigue Limit No Groove Lbs. per Sq.In.	Fatigue Limit Groove Lbs. per Sq.In.	Reduction Percent
X-4130	145,000	18	305	87,000	35,000	60
X-4130	207,000	13	420	101,000	44,000	57
2330	129,000	19	267	74,000	31,000	58
Nitralloy G with case	141,000	..	980[1]	82,000	82,000[2]	0
Without case	149,000	16	295	61,000	43,000[2]	30
Corrosion Resistant Steel 18-8	132,000	32	...	70,000	50,000	29
Aluminum Alloy 24ST	67,400	24	119	16,000	9,000	44
Magnesium Alloy 90 Mg 10 Al	47,000	7	70	18,000	7,000	61

[1] Vickers. [2] $\frac{D}{d} = 20$

are important factors in the selection of the alloy and the amount of cold work which can be performed without intermediate annealing.

Heat-treatable alloys are used almost exclusively for structural parts such as ribs, longitudinals, bulkheads, stressed skin covering, and fittings. They are selected on the basis of the high mechanical properties. High yield strength without loss of ductility is a characteristic of the heat-treated compared to the non-heat-treated alloys. Due to this characteristic there is some tendency to adopt the magnesium-silicon-chromium (53S) and magnesium-silicon (51S) alloys, which can be worked in the quenched condition and subsequently aged for parts which are now built of the non-heat-treatable alloys.

Heat Treatment

The essential steps in this procedure are well established. They are a soaking at a temperature in which one or more of the constituents—magnesium, copper, nickel, and silicon—go into solid solution; a quench rapid enough to retain this status of a super-saturated solid solution; and for optimum properties, an aging or precipitation treatment at relatively low temperatures.

The aluminum-copper-magnesium-silicon alloys (17S, 24S, and 195) in the quenched condition are quite stable below 0°C. At higher temperatures the ultimate strength and hardness increase due to the precipitation of $CuAl_2$ and Mg_2Si with a loss in ductility. The greatest change, however, is in the plasticity of the material as indicated by the increase in ratio of the yield strength to ultimate strength. The rate of hardening depends not only on the temperature but also on the condition of the alloy. A thin, cold rolled sheet will harden in a few hours at normal atmospheric temperature whereas a casting requires several months. At 300°F. the same tensile properties are attained in 16 to 24 hours. The aluminum-magnesium-silicon (53S) alloy does not age harden appreciably below 300°F. All the alloys are relatively easy to fabricate before aging although not to the same degree as in the annealed condition.

The mechanical properties are not so critical and may be obtained within fairly wide limits for the soaking temperature, rate of quenching, and temperature of aging. The corrosion resistance, however, is much more sensitive to these conditions. Aluminum and its alloys are susceptible to surface corrosion which causes pitting and the formation of aluminum oxide. The alloys containing copper and magnesium-silicide are susceptible to an inter-crystalline attack extending below the surface of the metal and causing a loss of ductility and strength. This corrosion is most damaging in relatively thin rolled sections, and in fact is seldom found in forgings or castings. Both types are accelerated in marine atmospheres. Pits and inter-crystalline decay may cause a marked reduction in fatigue resistance.

The susceptibility to inter-granular attack is affected sharply by the solution temperature and to a less degree by delayed quenching, Plate 2. These tests were made on 0.032 inch aluminum-copper-magnesium (24S) sheet, heated in a cyclone air furnace for 30 minutes, and quenched in cold water. The potential measurements were made in an electrolyte consisting of normal (58.45 gr. per liter) sodium chloride containing 9.1 ml. per liter of 30 percent hydrogen peroxide. The values represent an average taken at 5-minute intervals for 30 minutes after equilibrium was attained (usually 10 minutes). The corrodability was determined by immersing the specimen in the same solution as used for the potential measurements for a period of one minute and drying in air for 14 minutes. This cycle was repeated for a period of 24 hours. Metallographic specimens were examined to determine the presence of inter-granular corrosion. The potential measurements can be used only when the actual potential of each sheet (melts are not identifiable) is determined on a cold water quenched specimen which indicates no inter-granular corrosion in order to establish a base line. Single potential measurements will not identify materials susceptible to inter-granular corrosion since the potential values may vary with different lots of material over a range of 25 millivolts due to slight variations in chemical composition, whereas the change from pitting to inter-granular may occur within a difference of two millivolts.

Cold water has been established as the most satisfactory medium for quenching since a rapid cooling rate improves corrosion resistance. Quenching oil is superior to hot water or air.

Alclad sheet is less affected by the variables of heat treatment. The solution temperature zone can be wider and the rate of cooling slower than in the case of the uncoated alloy, provided the alloy constituents in the core have not diffused to the surface of the sheet which very seldom happens and is an indication of severe abuse.

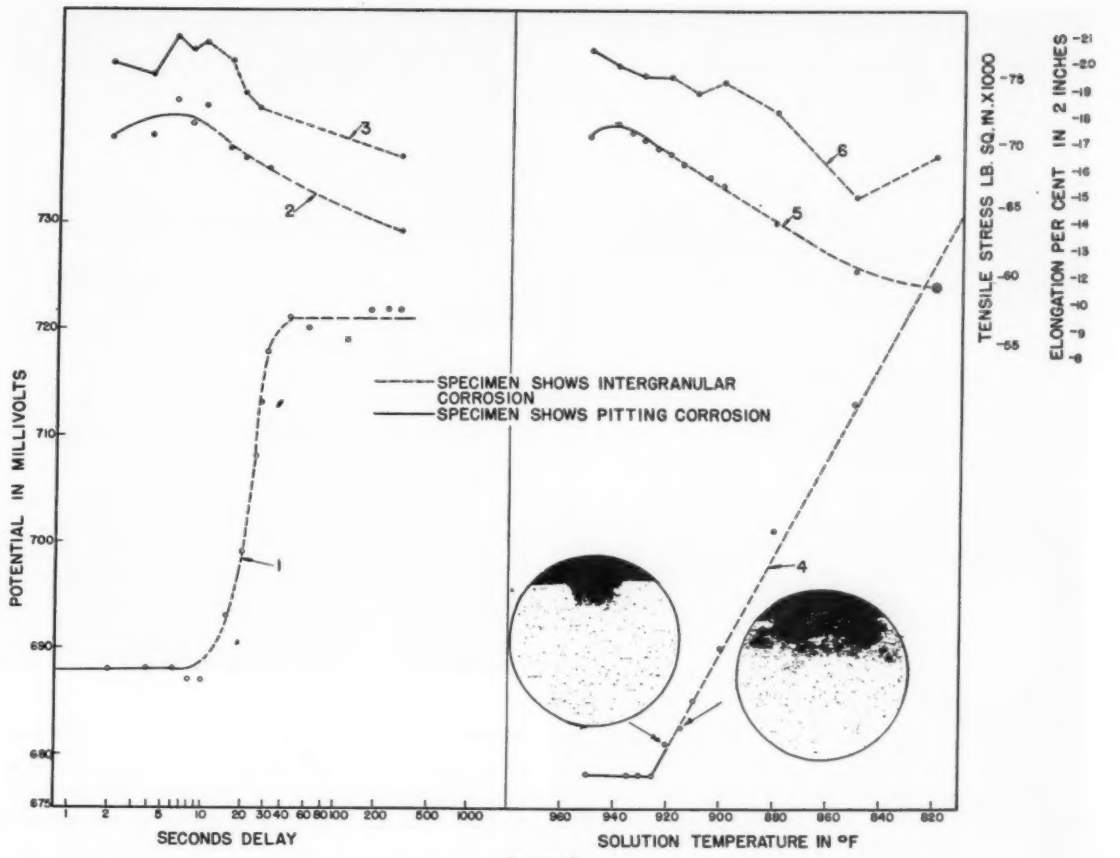


PLATE 2.

No. 1. Seconds delay *versus* Potential (millivolts)
No. 2. Seconds delay *versus* Tensile stress
No. 3. Seconds delay *versus* Elongation in 2 in. (percent)
No. 4. Solution Temp. °F. *versus* Potential (millivolts)
No. 5. Solution Temp. °F. *versus* Tensile stress
No. 6. Solution Temp. °F. *versus* Elongation in 2 in. (percent)

Corrosion in service is practically always due to the presence of an electrolyte consisting of water and a soluble material such as sodium chloride, lead bromide, sulphur compounds from soot, alkali dust, acids from used lubricating oils, and ingredients in cleaning compounds. If the conditions are such that moisture cannot evaporate freely and components with different electrical potentials are in contact, the corrosion is more severe (Fig. 1(a)).

The Air Corps has made a large number of exposure tests on a tidewater rack in Biscayne Bay, Florida. The test panels are immersed at high tide only. These tests have been accepted as indicative of corrosion which may be expected in coastal service since the character of the corrosion is similar and materials and practices which have given the best results on the test rack have been the most satisfactory in service, and those showing relatively greater corrosion on test have corroded in service. The general conclusions from the data which have been accumulated are briefly:

(a) The aluminum alloys, except 17S and 24S, have a high degree of corrosion resistance. Slight pitting may occur in seams or under accumulations of mud, barnacles, or other foreign substances. 17S and 24S will lose ductility and strength from inter-granular corrosion. This can be eliminated by the use of a pure aluminum coating (Alclad) which is also satisfactory for spot welded seams. Air quenched Alclad sheet 0.032 inches in thickness is satisfactory. The use of a non-metallic filler or coating in seams is desirable in all cases and essential where unlike metals are in contact. The several insulating mediums which have been tested in order of merit starting with the best are:

Neoprene Tape (riveted or bolted seams only).
Zinc Chromate Primer (riveted and spot welded seams).
Airplane Cloth soaked in solution of zinc-chromate.
Electrician's Friction Tape and Marine Glue.
Electrician's Friction Tape.
Airplane Cloth impregnated with varnish.
Airplane Cloth impregnated with Marine Glue.
Iron Oxide Primer.

X-4130 steel, brass, Monel metal, corrosion resistant steel (18-8), cadmium plated brass, and cadmium plated steel are in order in relation to damage from corrosion.

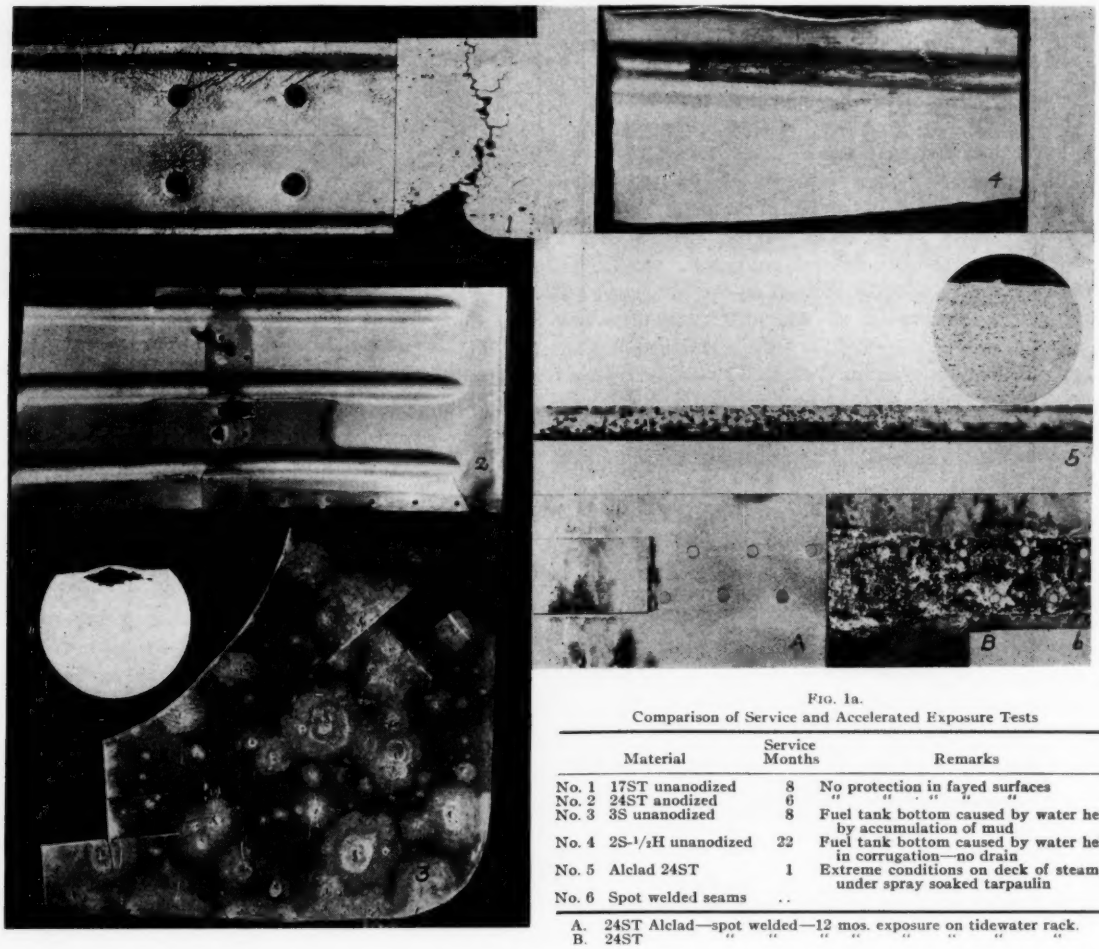


FIG. 1a.
Comparison of Service and Accelerated Exposure Tests

	Material	Service Months	Remarks
No. 1	17ST unanodized	8	No protection in fayed surfaces
No. 2	24ST anodized	6	" " " " "
No. 3	3S unanodized	8	Fuel tank bottom caused by water held by accumulation of mud
No. 4	2S-1/2H unanodized	22	Fuel tank bottom caused by water held in corrugation—no drain
No. 5	Alclad 24ST	1	Extreme conditions on deck of steamer under spray soaked tarpaulin
No. 6	Spot welded seams	..	

A. 24ST Alclad—spot welded—12 mos. exposure on tidewater rack.
B. 24ST " " " " " " " "

The unplated X-4130 was badly rusted and the aluminum alloys to which it was attached, including the Alclad, were badly pitted in the faying surface. The cadmium plated steel was intact with no pitting of the aluminum except in the case of 24ST. The pitting of the aluminum alloys in contact with Monel was not much better than bare X-4130, whereas 18-8 showed no pitting of Alclad or 52S.

The degree of corrosion in rivets and riveted joints is a function of the potential difference between the rivet and the sheet and current density at the anode. When the rivets form the anode of the cell the current density is much greater than if the sheet were the anode due to the large difference in area of the two surfaces. It was found that when rivets and sheets are of the same composition, corrosion is likely to concentrate on the rivet probably as a result of the higher single potential of the rivet due to cold working in the riveting operation. In riveted seams in 24ST alloys selective attack always occurred on the aluminum alloy rivets no matter what the composition, although rivets of 2S and 53ST suffered the severest attack. In no case was rivet corrosion apparent in seams in 24ST Alclad or 52S. In the case of spot welds in 24ST intercrystalline corrosion is very rapid. However, in the case of 24ST Alclad the spots are protected by the Alclad coating and there is no corrosion (Fig. 1(b)).

CASTINGS

Aluminum alloy castings are used for a large variety of airplane parts ranging in weight from a fraction of an ounce to several hundred pounds. Castings are generally molded in green sand although dry sand, permanent mold, and pressure die castings are used for a few parts. Sand castings have the advantage of facility in making changes in design, and relatively low cost for small production. Dry sand is used when it is necessary to reduce porosity due to gas from the mold but a moderate amount of pin-hole porosity does not affect the usefulness of castings for most applications. Permanent mold castings from a metal mold can be made to more accurate finished dimensions than sand castings, and more rapidly, but the alloys are generally modified to improve castability and the mechanical

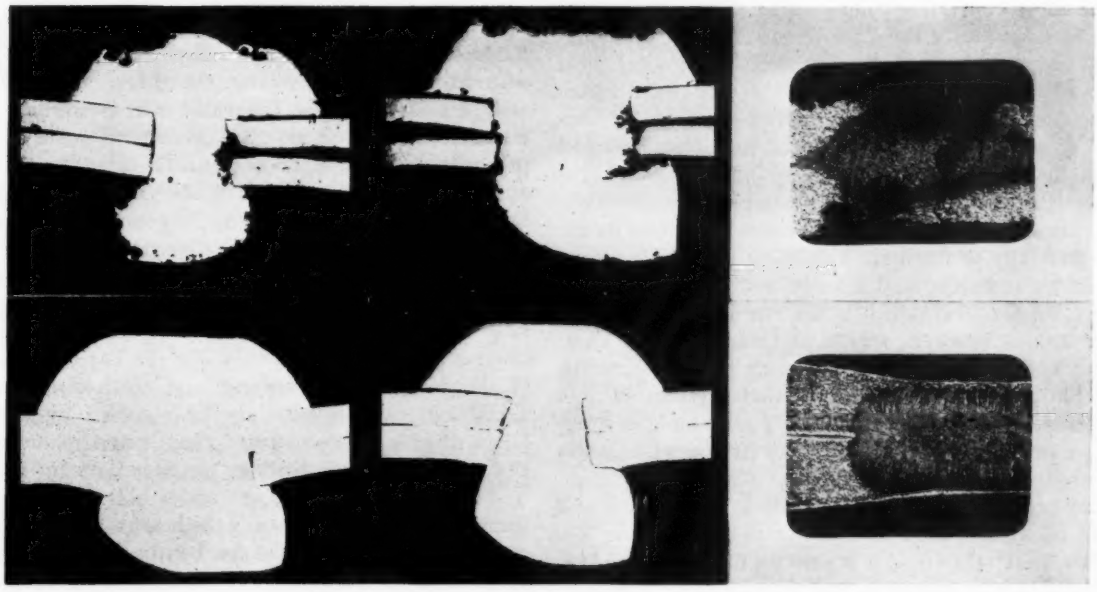


FIG. 1b. TIDEWATER RACK—6 MONTHS.

Upper	—Panel		—24ST		24ST
	Rivet	17-ST		A-17ST	Spot Weld (medium size)
Lower	—Panel		—24ST Alclad		24ST Alclad
	Rivet	17-ST		A-17ST	Spot Weld (maximum size)

properties are no higher than for the heat-treated sand castings. Pressure die castings made to an accuracy of thousandths of an inch have tensile properties comparable to heat-treated sand castings but are never free from internal cavities which render them unsuitable for airplane parts subjected to vibration, but quite satisfactory for gear housings, cases, battery containers, and similar parts.

It is the foundryman's problem to produce uniform castings free from mis-runs, cold shuts, shrinkage, and heavy porosity, which are due to gating, pattern equipment, condition of the sand, and other foundry operations. The designer should take into consideration the effect of thin and heavy sections which not only affect the mechanical properties on account of the different rates of cooling in the mold due to variation in thickness, but also pouring temperature which must be high enough to avoid mis-runs. The mechanical properties given in the specifications are obtained on separately cast test bars cast under optimum conditions except in the case of Air Corps specifications which require that the bars be poured within 20° of the pouring temperature of the casting so that the metal in the test bars will be more representative of the metal in the casting. This does not insure that the mechanical properties of the casting are equal to the test bar since there may be several different thicknesses in a single casting. The general relationship between individual cast test bars and specimens cut from castings has been determined for a large number of parts and is summed up in the requirement incorporated in Air Corps specifications which states that the average tensile strength and yield strength for the test specimens machined from the thinnest section, heaviest section, and intermediate section of a casting shall not be less than 75 percent of the values given for separately cast test bars and the elongation shall not be less than 25 percent. This has been further recognized in the requirement for strength of aircraft (A.N.C. 5), which requires that the test bar values be reduced 50 percent when used for determining allowable stresses. A proof load test of a casting is the most satisfactory method of determining its conformance to the design requirements provided the loads can be applied in a manner simulating those in service. It is not difficult when only simple loading is involved, but many castings are too complicated for adequate analysis. The cost of such tests may be prohibitive when the casting is designed to resist shock or repeated loads.

The alloy, Table 1, is selected on the basis of individual properties for the particular application. Heat-treated alloys are most suitable for parts which carry a relatively high stress. The higher yields strengths obtained by accelerated aging of these alloys are particularly desirable since yield strength is less affected by change of section within a casting and is the factor which controls the permanent distortion under load. The highest mechanical properties and corrosion resistance are obtained from alloys made with ingot of high purity. In the order of resistance to corrosion from marine exposure, the aluminum-magnesium alloys are best, with the aluminum-silicon alloys next, and

the alloys containing copper either as an alloying element or impurity the least resistant. The aluminum 3 percent magnesium alloy on account of its low yield strength has not been extensively used for airplane parts. Where high strength is unnecessary and corrosion resistance is an important factor such as fuel line fittings and pump bodies this alloy is quite satisfactory. The 10 percent magnesium alloy has the highest tensile strength of any of the cast alloys and its use is gradually increasing. This alloy requires a special foundry technique and is more costly than the 4 percent copper alloy which is the one generally selected for fittings, brackets, wheels, and similar parts. Castings have proved very satisfactory except where the amplitude of vibration is such that a relatively high fluctuating stress is established. For example, castings have failed when used for terminals for drag wires, masts for radio loops, and hinge fittings. The 5 percent silicon alloy can be cast free from porosity in thin sections and can be welded without difficulty to aluminum or low alloy sheet; therefore, it is used for filler necks, sumps, and other attachments to fuel and oil tanks. The heat-treated 7 percent silicon alloy is applicable for similar purposes requiring greater strength such as valves in pressure lines.

The copper-nickel alloys are used almost exclusively for cylinder heads of air-cooled engines because of their superior tensile properties at elevated temperatures. They have relatively high hardness and are suitable for lightly loaded bearings. The two non-heat-treated alloys, 4 percent copper 3 percent silicon and 8 percent copper 1 percent silicon, are used for small unimportant castings in airplanes or engines. Due to their low strength and elongation they are not suitable for airplane parts. The 4 percent silicon 1 percent copper alloy on account of better castability is used for larger and more intricate castings such as crankcases, oil pans, cylinder jackets, and heads for liquid-cooled engines.

Radiography is employed to check foundry practice and establish the correct technique for obtaining a sound casting and in special cases for detecting blowholes prior to costly machining. For this purpose it is an admirable inspection tool. It does not indicate mechanical properties.

Forgings and impact extrusions are usually preferable to castings on account of the higher mechanical properties and greater uniformity between light and heavy sections. 14S is used extensively for small and medium sized airplane forgings. 17S is sometimes specified on account of its better corrosion resistance. 25S has been used almost exclusively for propeller blades. A51S has better forgability for large complicated parts such as engine crankcases than the above alloys. X73S is used for the same purpose and has higher mechanical properties. 32S and 18S are piston alloys.

Magnesium Alloys

Magnesium is not used as a structural material but when alloyed with aluminum, manganese, zinc, silver, and occasionally other elements such as silicon and cadmium, the mechanical properties are greatly improved and the strength-weight ratio compares favorably with other structural materials. These alloys have the lowest density of any of the commercial metals which are available for airplane construction, Plate 1. The tensile properties of the cast alloys compare favorably with many aluminum alloys and it would be possible to replace the latter with a saving in weight of approximately 35 percent, except for the lower modulus of elasticity, Brinell hardness, and notch sensitivity. Equal rigidity can generally be obtained by larger fillets, thicker well supported flanges and reinforcing ribs, and the lower hardness counteracted by using bushed holes, larger washers under bolts heads, and similar methods for increasing the bearing area. Notch sensitivity is compensated for by the same methods used for increasing the rigidity and by avoiding sharp edges. The castings are serviceable for wheels, engine housings, brackets, and similar parts. The relationship between the strength of the test bar and the casting is very similar to that for aluminum alloys and similar precautions should be taken in design. The wrought alloys, M and J, are about equal to the aluminum alloys in specific density but they have lower hardness and require heating for many forming operations. They can be used to advantage only where the latter are heavier than actually required to satisfy the stress analysis: for example, oil tanks, in which practice has shown that a minimum thickness of metal is necessary to prevent damage in service. Magnesium alloy tanks may be 35 to 45 percent lighter than those of aluminum alloy. The 10 percent aluminum alloy has a high specific density but is available only in hot pressings. A high strength magnesium alloy with reasonable corrosion resistance would have a wide usage.

The chemical instability of magnesium alloys under marine conditions has been the principal factor in retarding their application. In the case of engine castings corrosion is inhibited to a degree by the coating of oil and the absence of the accumulation of water. There have been cases of aggravated corrosion which have led to an intensive search on the part of the magnesium industry to obtain more resistant alloys. The magnesium-aluminum-zinc-manganese alloy (H, AM-265) has much better salt water corrosion resistance than the 10 percent alluminum alloy (G, An-240) (Fig. 1(c)). Am-403 is used for parts welded to sheet. Magnesium alloys require protection of the surface. This is generally a combination of chemical treatments and organic coatings. The usual treatment is an immersion in a solution of nitric acid and potassium dichromate, generally before and after machining. The treatment is removed prior to welding but should be applied im-

mediately after the welding is complete. A later development is the anodic treatment. These treatments give about equal protection when painted with primer and enamel or lacquer.

Magnesium alloys have not been used for fuel tanks in this country although apparently satisfactory in foreign countries when a capsule is placed in the tank to counteract the attack of the chemicals used for the anti-knock. Used engine oil containing 2 percent of 0.2 percent hydrobromic acid did not corrode the 1.2 manganese alloy immersed for 33 days at 212°F.

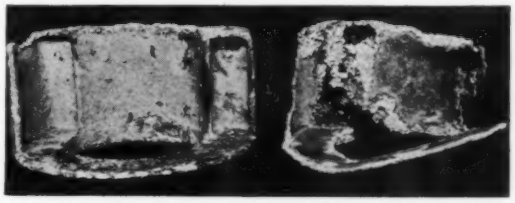


FIG. 1c.

	Chemical Composition Al	Zn	Mg	
Left	6	3	90	Treated and painted castings, tidewater 6 months
Right	10	.	90	" " " " " 3 weeks

STEEL

Chrome-molybdenum steel, SAE-X-4130, has fulfilled the requirements of the aircraft industry for a steel which is easily fabricated by welding in the normalized condition without appreciable loss in strength, and which is capable of being heat-treated to develop a wide range of mechanical properties. It is used extensively for structures, axles, tail wheel knuckles, and stamped and forged fittings. For heavy sections, high tensile properties cannot be obtained consistently except by quenching in water. Since this may cause cracks in fittings of variable cross-section, SAE-4140 is more generally used for such parts. Welding is questionable if the carbon limit exceeds 0.38 percent unless the base metal is pre-heated. The nickel-chromium-molybdenum, SAE-4340, which is widely used for crankshafts and master rod forgings for aircraft engines, is a deep hardening steel suitable for airplane parts of heavy section. Parts heat-treated in excess of 180,000 lbs. per sq.in. should be simple sections of uniform thickness or gradual taper with liberal fillets at the corners and rounded edges. A high notched bar impact value is desirable. An alloy steel which will develop the following properties is desirable but not available for aircraft construction.

Tensile Strength, lbs. per sq.in. (oil quench), 275,000
Yield Strength, lbs. per sq.in., 75 percent of Ultimate Strength
Elongation, 2 in., 15 percent
Impact, Izod, 35 ft. lbs.
Bend 90° without cracking on the outside of the bend in a $\frac{1}{2}$ in. round
Fatigue Strength, lbs. per sq.in., 50 percent of Ultimate Strength
Weldable

The applications of carbon steel are confined to brake drums, nuts, tie rods, springs, low stressed sheet metal fittings, ferrules, and minor utility and screw machine parts. The use of free machining carbon steels containing high phosphorus and sulphur should be restricted to parts not subjected to vibration. SAE-2330 is readily available in the form of cold drawn bars and wire for cold heading and is used for a large number of screw machine parts designed for ultimate tensile strengths of 125,000 to 150,000 lbs. per sq.in., such as bolts, clevises, and universal joints. There are many carburizing steels and higher carbon oil hardening steels suitable for parts subjected to wear, such as gears, racks, and pins, (SAE-6150, 3250, 1015, 2315, 3312, and 2515). The carburizing steels with the higher alloy content have core strengths up to 160,000 lbs. per sq.in. The nitriding steels are also used in this field, with a surface hardness equivalent to 950 to 1025 Brinell compared to 650 to 825 Brinell, Rockwell C-58 to C-63, for carburized steel. Nitriding can be accomplished with a minimum of warping and distortion and produces a case which has a relatively high fatigue strength which is not reduced by a circular notch or similar stress raiser (Table 2).

Steel castings manufactured from alloy steel and heat-treated are comparable to forgings in tensile strength but have lower ductility and notched bar impact strength. The modulus of elasticity, yield strength, and ductility are superior to equivalent properties for the high tensile copper base castings. The properties of the casting are lower than the separately cast test bars (Fig. 2). The fatigue-tensile ratio is lower than in the case of bars or forgings.

Corrosion-resistant steel may be divided into two classifications (a) ferritic; (b) austentic. The ferritic grades are SAE-51335, 51210, and 51710 with the addition of about 2 percent nickel. The mechanical properties of these steels can be modified by quenching and tempering, analogous to the low alloy steels. Medium carbon 13 percent chromium is notch sensitive to suddenly applied loads and is not suitable for parts containing holes and notches which are subjected to impact loads. Its use is confined to an occasional small bearing or bushing. The low carbon grade is less sensitive except in the range of tempering temperatures from approximately 750° to 1050°F. The 16 percent chromium 2 percent nickel steel is also less notch sensitive and more corrosion resistant, and is used for clevises, hinge pins, and similar parts on airplanes operating under marine conditions. These steels are apt to be excessively brittle after welding. For maximum corrosion resistance the surface should be free from scale and highly polished. These steels are magnetic.

FIG. 1d.

	Chemical Composition C	Cr	Ni	
Left	0.09	19	8.8	Pits at edge of spot welded seam, tidewater rack 12 months
Right	0.11	12	...	Pits in hardened steel screw from 18.8 wing after 6 months service.

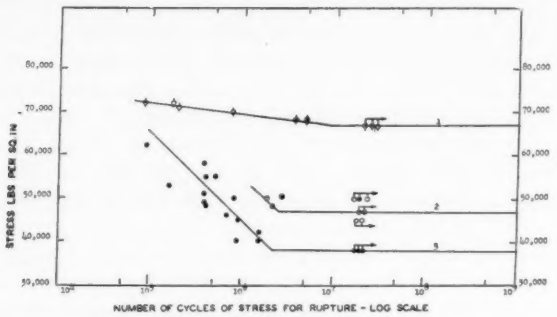


FIG. 2.

Steel Castings

No.	Chemical Composition C	Mn	Cr	Mo	Si	Cu	Mechanical Properties: Tensile Strength Lb. per Sq. In.	Yield Strength Lb. per Sq. In.	Elongation 2 In. Per-Cent	Reduction of Area Per-Cent	Brinell Hardness	Fatigue Str. Tensile Str.
1	0.39	1.39	0.62	0.29	0.53	...	125,000	103,700	21	29	277	0.54
2	0.19	1.32	...	...	1.36	1.47	133,800	.....	14	21	289	0.34
3	0.19	1.32	...	...	1.36	1.47	142,300	119,000	5	8	309	0.27

Nos. 1 and 2—Specimens machined from separately cast test coupons.
No. 3—Specimen machined from landing gear casting approximately cylindrical and 1-inch wall thickness.

The austentic steel (18-8), with a minimum chromium and nickel content of 17 and 7 percent, respectively, is not hardenable by heat treatment; in fact, quenching in water from a temperature of from 1850° to 2050° softens the steel and renders it suitable for deep forming. The mechanical properties are profoundly altered by cold work, and by this means the strength-weight ratio can be increased so that it exceeds that of the low specific gravity alloys. This applies only to relatively thin material in the form of sheets or wire products. This steel is non-magnetic in the annealed or fully austenitic condition, but the permeability increases with cold work and hard drawn wire may have a permeability greater than 2 at 150 oersteds. Increasing the nickel content lowers the permeability. Soft annealed 18-8 is used for exhaust stacks, rings, and appurtenances operating at elevated temperatures and for parts which must be corrosion-resistant and require deep forming such as carburetor floats. When this steel is cooled rapidly from a high temperature it shows a homogeneous austenitic structure under the microscope with carbon and other constituents in solu-

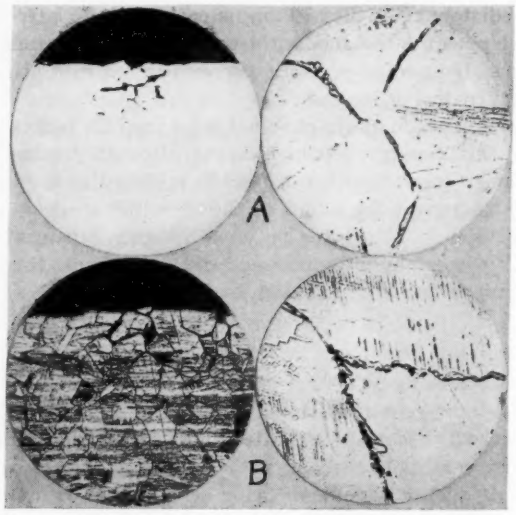


FIG. 3. Intercrystalline breakdown in exhaust stacks in service (no stabilizing elements). Magnification of left-hand pictures, 100; magnification of right-hand pictures, 1300. Right-hand pictures show precipitated carbides.
A. No etch. 768 hours, C 0.07, Cr 18.2, Ni 8.9.
B. Etch: HCl, HNO_3, Glycerol. 109 hours, C 0.05, Cr 17.8, Ni 9.3.

tion. When re-heated between 900° to 1400°F. during fabrication or in service chromium carbides are precipitated at the grain boundaries (Fig. 3). This removes chromium from the solid solution and the steel rusts in a shorter time and is susceptible to inter-granular corrosion. During welding there is always a zone which has been heated to the critical temperature range for a sufficient time for the precipitate to form. Titanium or columbium additions prevent deletion of chromium probably because these elements have a greater affinity for carbon, hence, these steels are referred to as stabilized. It is essential that stabilized 18-8 steel be used within the above temperature range. It is necessary that the filler rod contain stabilizing elements to prevent dilution of the base metal. Columbium has less tendency to burn out and is preferable to titanium for this purpose. No inter-crystalline embrittlement has been found in service in exhaust stacks containing titanium or columbium.

Most applications of 18-8 steel require a higher strength and better surface finish than can be obtained in the annealed material. Cold rolled and cold drawn products are used for fire walls, ammunition chutes, tanks, and the primary and secondary structural parts of the airplane. For structural purposes, the high tensile sheet with an ultimate strength of 185,000 lbs. per sq. in. is required for a favorable weight comparison with other materials. The yield strength arbitrarily taken as the stress at a permanent set of 0.002 in. per in. is equal to 75 percent of the ultimate strength which is higher than the ratio for the heat-treated Alclad aluminum alloys which have demonstrated satisfactory serviceability in regard to plastic deformation. Speci-

fications for 18-8 are restrictive only in the minimum requirements for nickel and chromium. This permits a wide range in the strength-ductility relationship since the chromium and nickel contents influence the rate of hardening under cold work. There is no conclusive evidence that high elongation is necessary for aircraft structures although it may assist in fabrication. Forming is generally accomplished by drawing through rolls or dies. Pressing or stamping operations are difficult. Under tidewater exposure referred to previously in connection with aluminum alloys, the 18-8 steel stains and pits, especially at the edge of a fayed surface (Fig. 1(d)). The corrodability is not affected to a measurable extent by quite wide variations in the percentages of nickel and chromium. The addition of 3 per cent molybdenum has a marked effect in increasing the resistance to such attack. The use of a compound containing copper-oxide and petrolatum adds further protection at the seams. Spot welds when properly made show very little selective corrosion and stabilizing elements are unnecessary.

Wire

The products from the wire mill represent the optimum in mechanical properties, and are obtained by judicious combination of heat treatment and cold work. The principal tension members of the aircraft structure have been steel wire since the construction of the original Wright airplane. Hard drawn tinned carbon steel wire, and tie rods manufactured from $3^1/_2$ percent nickel steel and half hard carbon steel, cadmium plated, and from corrosion resistant steel (18-8) have been used successively for wire bracing in airplane trusses. The tie rods are manufactured from cold drawn wire by cold swaging or cold rolling to a reduced cylindrical, square or elliptical section. The majority of failures have been in the streamline tie rods and were caused by torsional vibration induced by instability under aerodynamic forces. This condition has been improved by rigging the airplane by the use of tensiometers and thus reducing the amplitude of vibration.

One of the most exacting applications of wire is the manufacture of springs. Many springs operate above the fatigue limit due to limitations on weight and size. The number of operating cycles is generally so low that this is a safe practice but when stress raisers such as decarburization pits, die marks, and nicks are present the reduction in fatigue properties may be critical. The wire for highly stressed springs should have a surface free from defects and magnaflux inspection should be made on the finished springs. Brittleness may be due to excessive hardness which can be controlled by tempering or from occluded gases from the plating operation. These can be driven off by a low temperature treatment at 400°F. for 3 hours. Springs coiled from surface ground chrome-vanadium steel wire and quenched and tempered to a hardness of Rockwell C-48 have been giving excellent service.

Cable

Cable controls are easily inspected, simple to operate, and relatively free from maintenance troubles, and have been replaced only to a limited extent by hydraulic or mechanical devices. An extra flexible cable, 7 strands with 19 wires, which will operate freely over pulleys has become standard. This construction has a relatively low tension modulus and high initial stretch. The load-stretch diagrams, Fig. 4, were obtained on 40 ft. lengths of $^3/_{16}$ inch cable, using dead loads. Prestretching for 3 minutes with a load equal to 60 percent of the rated strength reduces the stretch for this load approximately 12.5 percent and for 96 hours, 16.5 percent. The reduction in stretch is due largely to an increase in the modulus in the elastic range. The initial non-elastic stretch can only be compensated by applying to the control system a fixed tensile load from 6 to 8 percent of the rated tensile strength of the cable. This is apparent even after a pre-load of 94 percent of the rated strength for 3 minutes by which the modulus is increased to 18,100,000 lbs. per sq.in.

The endurance properties of cable are affected by the materials in the cable and pulley, the construction of the cable, ratio of pulley diameter to cable diameter, bearing or fit of the cable in the groove, and the cable tension. Pulleys manufactured from fabric impregnated with phenol-formaldehyde plastics have been used extensively because of the lower cable wear compared to metal pulleys. The fit of the cable in the groove need not be so close with the fabric pulley since the cable has a tendency to seat itself. The marked effect of the ratio of pulley diameter to cable diameter for $^5/_{32}$ and $^3/_{16}$ inch cable is indicated in Fig. 4. The tests were made on a machine, and in accordance with the procedure described in Air Corps Specifications 48-35 and 48-36. The cable from which these data were obtained was 7×19 pre-formed regular lay. The service life of non-pre-formed cable of the same construction may be less than 10 percent of the life of pre-formed cable. Warrington lay cable has approximately 15 percent less stretch than the regular lay but lower fatigue properties. The fatigue strength is greatly reduced by increasing the cable tension, Fig. 4. Service tests have demonstrated that the endurance characteristics and type of failure can be predicted from laboratory fatigue tests.

Corrosion-resistant steel cable has a lower tension modulus which increases the stretch about 25 percent over that of the carbon steel cable. It is slightly less magnetic and less wear resistant than carbon steel cable under normal atmospheric conditions. If salt water or the chemicals used in photography are dripped on the cable the corrosion-resistant steel gives a reasonable life whereas the carbon steel disintegrates rapidly.

Copper

The copper and copper base alloys have a very restricted usage in airplane construction on account of

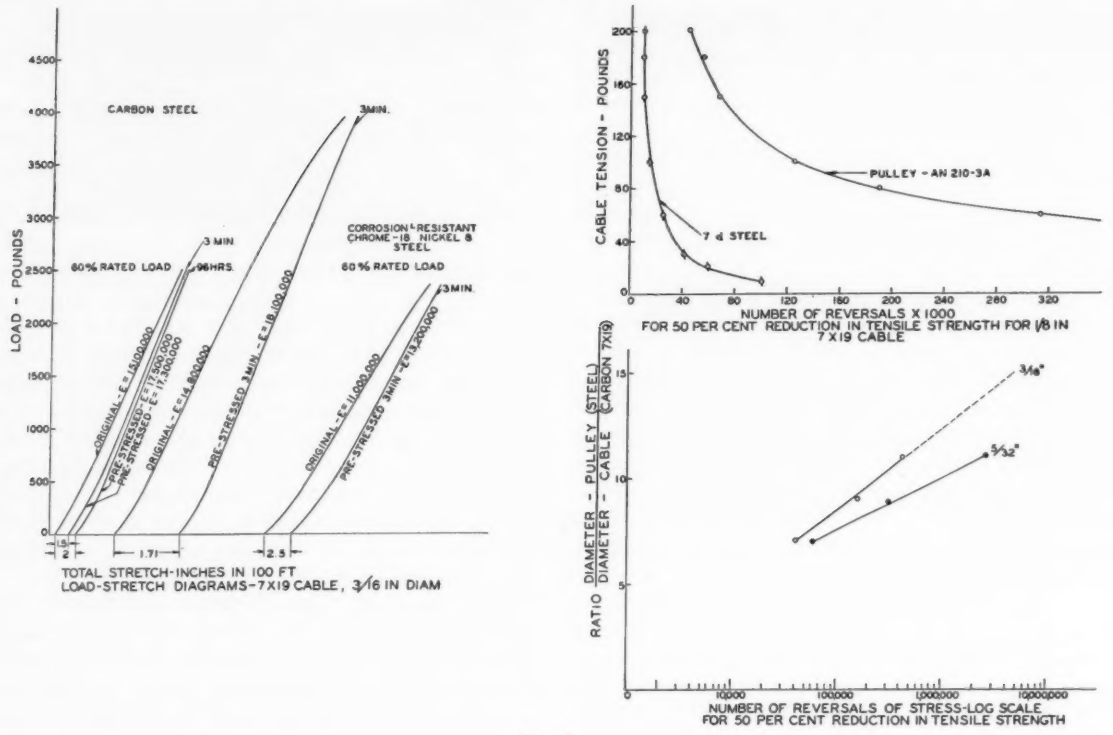

LOAD - POUNDS
CARBON STEEL
3 MIN.
3 MIN
60% RATED LOAD
96 HRS.
ORIGINAL - E = 15,000,000
PRE-STRESSED - E = 17,500,000
PRE-STRESSED - E = 17,500,000
ORIGINAL - E = 14,800,000
PRE-STRESSED 3 MIN. - E = 18,100,000
CORROSION-RESISTANT CHROME-18 NICKEL 8 STEEL
60% RATED LOAD
3 MIN.
ORIGINAL - E = 11,000,000
PRE-STRESSED 3 MIN - E = 13,200,000
1.5
2
1.71
2.5
TOTAL STRETCH-INCHES IN 100 FT
LOAD-STRETCH DIAGRAMS-7X19 CABLE, 3/16 IN DIAM
CABLE TENSION - POUNDS
PULLEY - AN 210-3A
7 d STEEL
NUMBER OF REVERSALS X 1000
FOR 50 PER CENT REDUCTION IN TENSILE STRENGTH FOR 1/8 IN 7 X 19 CABLE
RATIO DIAMETER - PULLEY (STEEL) / DIAMETER - CABLE (CARBON 7X19)
3/16"
5/32"
NUMBER OF REVERSALS OF STRESS-LOG SCALE
FOR 50 PER CENT REDUCTION IN TENSILE STRENGTH

FIG. 4.

their high specific gravity compared to aluminum alloys and low modulus and hardness compared to iron and nickel base alloys. The usual applications involve electrical properties, corrosion resistance, and anti-frictional properties, often under conditions where the mechanical strength is of secondary importance. Copper is used principally for electrical conductors. Tubing which was formerly the standard for utility lines has been replaced to a large extent by aluminum alloys. High brass, an alpha solid solution of zinc in copper, has lower strength and corrosion resistance than naval brass and should be restricted to small nuts, electrical fittings, screws, and parts where severe cold working and machinability are the primary considerations. Naval brass has a higher zinc content and mixed alpha-beta crystallization. When the grain size is controlled and the material is free from strains as indicated by the mercurous nitrate test it is a useful alloy for bolts, turnbuckle barrels, and other adjustable connections. Manganese-bronze, a similar alloy with the addition of small percentages of aluminum and manganese, is used in wrought and cast form. The relatively low yield strength and hardness of these alloys may lead to excessive wear at pin and bolt holes under fluctuating loads, and liberal bearing areas are required unless steel bushings are employed.

Copper-tin alloys have given general satisfaction for anti-friction bearings. The wrought 5 percent tin alloy, phosphor-bronze, is used when the strength and hardness of the high leaded cast bronze is insufficient. For better anti-frictional properties but lower mechanical properties the 70 copper 30 lead alloys are used. Cast leaded red brass and extruded high brass are used for low pressure fuel, coolant, and oil line fittings. Gun metal is superior for high pressure fittings. Silicon-bronze castings are equally suitable. This alloy in the form of tubes has been used successfully for fuel lines.

Aluminum-bronze and beryllium-bronze are the only copper base materials which have been used in aircraft construction which are heat-treated to improve the physical porperties. Aluminum-bronze covers a number of alloys containing not less than 80 percent copper, with from 7 to 12 percent aluminum, with or without the additions of iron, nickel, manganese, and other elements. Copper and aluminum form a solid solution up to approximately 10 percent aluminum. This alpha phase is relatively soft and ductile and is generally used in the wrought condition without heat treatment for bolts, pins, and valve guides for engines of low horsepower, and miscellaneous bushings requiring corrosion resistance. With an aluminum content greater than 10 percent or the addition of 1 to 3 percent iron the alloy is structurally a mixture of alpha and a eutectoid phase. These alloys are more difficult to extrude and are generally used in the form of sand castings which can be heat-treated (Table 1) to develop a tensile strength of 80,000 lbs. per sq.in. and a Brinell hardness of 200. A satisfactory heat treatment consists of a cold

water quench from 1650°F. and a draw at approximately 800°F. The ductility as measured by an elongation of 6 to 10 percent is sufficient for many applications such as gears, worms, propeller hub cones, and nuts for retracting gears.

Beryllium-bronze castings are used for propeller hub cones, gears, and bearings blocks. The wrought alloy is used in the form of wire or strip for springs. The springs can be formed and subsequently heat-treated, producing a greater elastic range than in the case of the cold worked phosphor-bronze although not equal to steel. The corrosion-resistance in salt water is equal to phosphor-bronze.

Nickel

The role of nickel in improving the ductility and toughness of structural steels is well established. The higher percentages confer corrosion-resistance and strength at elevated temperatures. It is also effective in aluminum alloys for the latter purpose. Pure nickel has high ductility and fatigue resistance (Plate 1). The nickel base alloys containing either copper, chromium, or molybdenum as the principal alloying element are ductile, corrosion-resistant in marine atmospheres, and have relatively high strength at elevated temperatures. This combination of properties can be used to advantage in the parts used for conveying and distributing exhaust gases. The nickel-chromium (Inconel) has given very satisfactory performance for this purpose. It is a uniform product which can be fabricated into complicated shapes by deep forming and welding. The material is entirely free from inter-crystalline embrittlement and does not stain under conditions which may cause rusting of other materials used for similar purposes.

Monel metal with the addition of aluminum is heat-treatable and has mechanical properties equal to cold-rolled 18-8 steel and heat-treated 16-1 steel. It is used interchangeably with these steels for tie rods, terminals, pins, and bolts.

The nickel-molybdenum alloys are more costly and difficult to machine but have a place in parts under high stress at elevated temperatures.

Wood

There has been little progress in this country in the application of wood in airplane construction in the past several years. At the present time experimental developments on compressed and impregnated wood for propeller manufacture are being carried out which may have wider application. Impregnation is accomplished by subjecting the wood to low pressure prior to immersing in the liquid, and then applying high pressure. The specific gravity and mechanical properties of the wood are increased and dimensional changes are reduced. The following properties were obtained after impregnating pieces of lumber $^{7}/_{8} \times 3 \times 30$ inches with methyl-methacrylate liquid monomer under a vacuum of 26 inches, followed by a pressure of 200 pounds. The polymerization was carried out at elevated temperatures.

		Moisture Absorption Soaking 60 Hr. Percent	Specific Gravity	Compression Parallel to Grain Lbs. per Sq.In.	Modulus of Rupture Lbs. per Sq.In.	Modulus of Elasticity Lbs. per Sq.In. $\times 10^6$
Spruce	Untreated	50	0.41	8,400	12,300	1.4
	Treated	10	0.74	12,400	16,000	2.3
Maple	Untreated	49	0.67	9,800	13,900	1.9
	Treated	9	1.11	15,600	20,000	2.1

An improvement in plywood has been accomplished by the use of phenol formaldehyde and vinyl resins. The former is manufactured in thin films which are laid between the sheets of veneer and the assembly is cured under heat and pressure. This may be done in flat platen presses or in molds with curved contours. The vinyl resins may be handled in the same way or as a liquid glue and are cured at a lower temperature and pressure than the thermo-setting resins. The impregnation of the wood is a negligible amount with either resin so that the mechanical properties are determined by the species of wood, arrangement of plies, and moisture content.

A glued joint fails in service from breakdown of the glue due to chemical change, attack from molds or absorption of water. Plywood breaks down from failure of the glued joint or failure of the wood. The Forest Products Laboratory have summarized the results of tests of plywood fabricated from casein, phenol formaldehyde and vinyl resins, and blood albumen glues. The joints made with artificial resins of the phenol type satisfactorily withstood four years of exposure under extremely severe test conditions. In the tests by continuous soaking in water the casein glue hydrolyzed at a relatively rapid rate, the artificial resin glues and blood albumen glues did not weaken. The casein glue was also attacked by molds and failed in five months exposure to an atmosphere of 97 percent humidity. The artificial resins and blood albumen resisted attack but did not prevent the attack on the wood so that after three to four years the wood had rotted to a marked degree. Exposure to cycles of alternating soaking and drying indicated the superiority of the phenol formaldehyde resins. These tests indicate that the plywoods suitable for airplane construction have been greatly improved but their satisfactory performance is dependent upon the paint films applied to the exterior surfaces to prevent moisture from entering the wood. With the large amount of research work being carried out at the present time in connection with artificial resins and protective coatings it is probable that a moisture, weather resistant coating will eventually be developed.

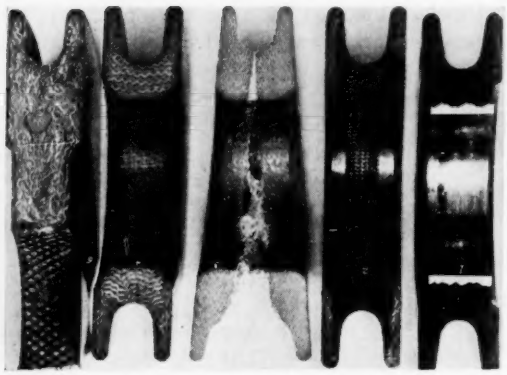


FIG. 5.

PLASTICS

Plastics are defined as moldable materials manufactured from organic compounds. This broad definition has been used to include plywood, steamed ash, and impregnated wood, but it would be preferable to avoid the use of the term for materials which are in common use under other names which are more descriptive. The organic plastics have been classified according to their behavior under temperature changes.

(A) Thermo-plastic–temperature-flow relationship is reversible. They can be remolded with the application of moderate heat and pressure which permits the fabrication of shapes by the airplane builder without expensive molding equipment.

(B) Thermo-setting–temperature-flow relationship is irreversible. The plastic in the final stage is infusible and cannot be remolded. Plastics are available in the form of powder, liquid, semi-converted and completely converted solids. Conversion to a usable solid form generally requires the application of heat and pressure under controlled conditions, and only in special cases is this operation being done by the airplane manufacturer. In the case of the thermo-plastic airplane dopes, solidification proceeds under normal conditions by the evaporation of solvents and plasticizers.

Thermo-plastic materials which are being used in the aircraft industry are cellulose nitrate and acetate, acrylates, vinyl-acetals, and styrene. These are used as coatings or fillers in combination with other materials to produce artificial leather and laminated glass, and directly in the form of cast or rolled sheet and molded shapes for windows, handles, knobs, and small accessories. Poly-styrene is used in the ring lighting of instruments on account of its heat resistance and ability to transmit light.

The thermo-setting resin is phenol-formaldehyde which is used for electrical parts, instrument and gear cases, pulleys, propeller chafing bands, gears, and miscellaneous parts requiring mechanical strength and hardness. With few exceptions the resin is mixed with fillers such as wood, flour, paper, and fabric. This permits a wide variation in specific gravity, mechanical, and electrical properties. The airplane pulley is an excellent example of the use of a phenol-formaldehyde plastic with fabric filler to produce a structural ele-

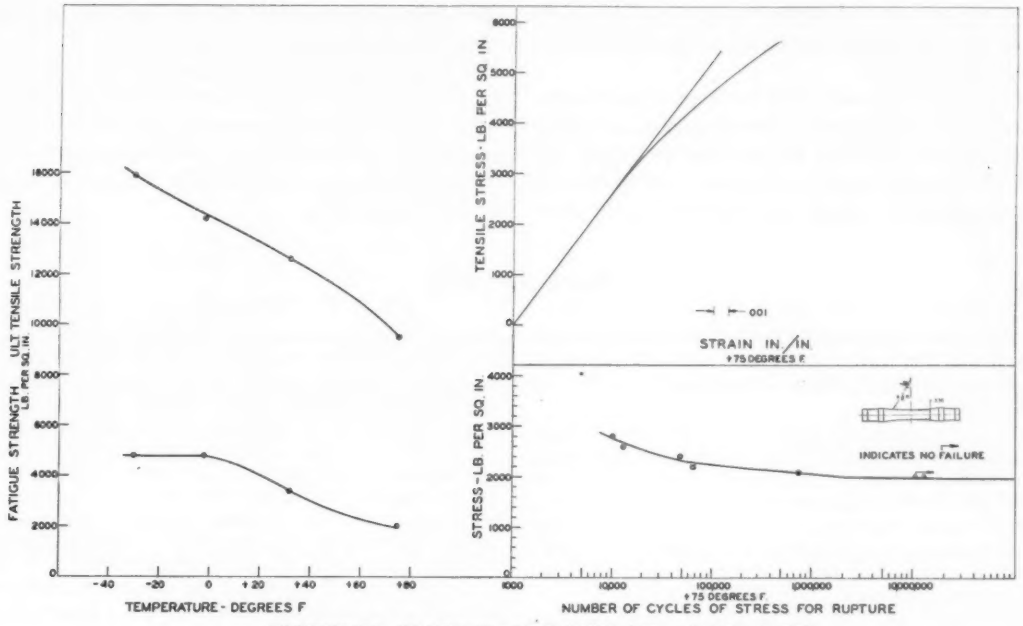
TABLE 3

Plastics—Average Values

Type	Grade	Spec. No.	Specific Gravity	Moisture Absorption 24 Hrs. Percent	Tensile Strength Lb. per Sq. In.	Flexural Strength Lb. per Sq. In.	Compressive Strength Flatwise Lb. per Sq. In.	Modulus of Elasticity Lb. per Sq. In. $\times 10^5$	Dielectric Strength Short Time, V./Mil.	Thermal Expansion per °C. $\times 10^{-5}$	Resistance to Heat Continuous °F.	Light Transmission Percent Orig.	Light Transmission Percent Exp.[1]	Burning Rate
Phenol Formaldehyde	Laminated Paper Base	71–484	1.4	1.3	9,500	16,000	35,000	12.5	700	2	260	Opaque	..	Very Low
Phenol Formaldehyde	Fabric Base	71–484	1.4	1.7	10,000	20,000	38,000	10	350	3	280	Opaque	..	Very Low
Phenol Formaldehyde	Macerated Fabric	71–484	1.4	1.5	6,500	11,000	26,000	..	375	..	300	Opaque	..	Very Low
Phenol Formaldehyde	Molded—No Filler	71–484	1.3	0.2	7,500	14,000	....	8.5	450	..	250	70	..	Very Low
Methyl Methacrylate	Cast Sheet	12014	1.2	0.4	8,500	10,000	8,000	4	500	8.5	125	94	90	Slow
Cellulose Acetate	Rolled Sheet	12025	1.3	2.5	8,500	6,000	10,000	2.3	1,500	13	140	82	73	Slow
Cellulose Nitrate	Rolled Sheet	12008	1.5	1.5	6,000	....	....	2.5	900	10	...	75	16	Very High
Styrene	Cast Sheet	....	1.1	0.0	7,000	7,000	13,000	5	600	7.5	155	85	..	Slow
Vinyl-Acetals	Sheet	....	1.1	1.3	9,000	11,000	....	..	10,000	..	...			
Cellulose Fiber	Hard Vulcanized	40231	1.05	35.0	7,000	13,000	25,000	..	200	..	...	Opaque	..	...

[1] Six months at Miami, Florida.

Sources—Directory, Modern Plastics, Oct., 1938, and Air Corps Reports and Specifications.


FATIGUE STRENGTH - ULT TENSILE STRENGTH LB. PER SQ. IN
TEMPERATURE - DEGREES F
TENSILE STRESS - LB. PER SQ. IN
STRAIN IN / IN
+75 DEGREES F
.001
STRESS - LB. PER SQ. IN
INDICATES NO FAILURE
+75 DEGREES F
NUMBER OF CYCLES OF STRESS FOR RUPTURE

PROPERTIES OF METHYL- METHACRYLATE - 1/2 INCH SHEET

PLATE 3.

ment. The resistance to splitting is increased if the filler follows the contour of the mold, similar to the flow lines in a forging (Fig. 5), since the laminated construction is relatively weak in a direction perpendicular to the lay of the laminations. It is probable that a similar construction with the proper combination of resin and filler would be satisfactory for wheels and similar parts produced in quantity. Thermo-setting plastic sheets have been used to a limited extent for the primary structure for gussets and reinforcing patches. They are superior to plywood since there is no shrinkage or swelling from changes in moisture content. No heavy sections, with the exception of propellers, have been constructed of plastics largely due to the inflexibility and high cost of the molding process for a relatively small number of parts.

The application of available plastics for the primary structure of an airplane is questionable. The mechanical properties are not well established. The data on the stress-strain relationships and flow at the operating temperatures which vary from $-40°$ to $+145°$F. are scarce, and those available are not comparable to similar tests on metals since the conditions under which the tests were made are often not given. Data on fatigue characteristics are practically non-existent. Without such data the aeronautical engineer is unable to intelligently design a structure. There are a large number of resins each of which can be processed so that the physical properties vary over a wide range. The types given in Table 3 represent a few which are being used in the aeronautical industry. Much higher tensile properties are possible, Caldwell and Clay report

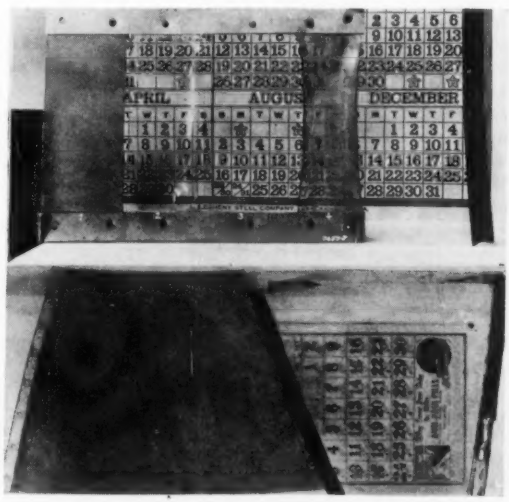


FIG. 6. Upper: Exposure on land rack, Miami, Florida, 6 months. 1. Cellulose Nitrate. 2. and 4. Cellulose Acetate. 3. and 5. Methyl methacrylate.
Lower: Service on airplane, Dayton, Ohio, 11 months. Left, Cellulose nitrate; right, Cellulose acetate.

36,000 and 26,000 lbs. per sq.in. for phenolic-wood and phenolic-fabric combinations, respectively. The fatigue curves, Plate 3, were obtained on a rotating beam machine with a standard specimen.

A single plastic does not possess all the characteristics desired by the aeronautical engineer and it is necessary to make a selection. The acrylate plastics are superior to cellulose acetate and cellulose nitrate where maximum light transmission and durability are desired (Fig. 6). Cellulose nitrate has poor durability

and is a fire hazard. Cellulose acetate is less costly and may have a limited application when not exposed to the direct sunlight.

Cellulose nitrate is still used for dope films because no completely satisfactory substitute is available. Acetate dopes do not have the moisture resistance and become slack under humid conditions. The addition of cadmium pigments retards the ignition of the dope films from incandescent exhaust particles and has reduced the fire hazard.

The application of transparent thermo-plastic sheet for nose sections, canopies, and similar parts is not entirely satisfactory on account of the necessity of using supporting metal structures. Molded parts with transparent bracing are a possibility, high cost being the principal deterrent.

Book Reviews

An Introduction to the Study of Air Mass Analysis, by JEROME NAMIAS, H. C. WILLETT, and B. HAURWITZ; The American Meteorological Society, Milton, Massachusetts, 1938; 122 pages, $0.75.

This booklet embodies the fourth edition of Jerome Namias' *Introduction to the Study of Air Mass Analysis*, an abbreviated revision of H. C. Willett's *Characteristic Properties of North American Air Masses*, and, included for the first time, a chapter on *The Norwegian Wave-Theory of Cyclones* by B. Haurwitz. A number of interesting and instructive atmospheric cross-sections and synoptic weather charts, have also been added to this revised and enlarged edition.

In the first series of articles, as in previous editions, Namias has discussed, in considerable detail, atmospheric stability, outlining the types of equilibrium with reference to lapse rates, the conservative properties of air masses, the plotting routine and interpretation of the Rossby Diagram, and finally, the elements of frontal and cyclonic structure. The articles have been revised with appropriate references or footnotes to clarify some of the points, which, in the light of later research, have been entirely changed or altered in certain details.

Following the discussion of the elements of cyclonic structure, there is given a chapter on the wave theory of cyclones by Haurwitz. He attacks the problem of the formation of cyclonic waves by giving a descriptive account of the mathematical theory, taking up in order the various types of common waves originating in a gas or liquid and then shows how the factors causing these waves operate together to produce cyclonic waves in the atmosphere. This excellent treatment of a very complex problem cannot fail to give the beginner a much better understanding of the nature of cyclonic wave formation or to convince the skeptic that waves do develop along a frontal system under favorable conditions.

The several excerpts following this chapter will serve to inform the reader of the results of more recent aerological investigations toward the solution of the causes of the formation of cyclonic waves.

Consideration of the tephigram, the plotting routine and its use, is given in the articles following the chapter on the Norwegian Wave Theory. Although this chart is being replaced by others it is still used to some extent for determining the energy relations for thunderstorm forecasting. Namias' last article deals with the characteristics of the various types of thunderstorms and points out synoptic indications which are favorable for their development.

The list of suggested readings on air mass analysis and related subjects has been enlarged to include all the more recent publications since the third edition of this booklet was issued in 1936.

Dr. Willett has revised and enlarged his chapter on the characteristic properties of air masses. Table II, which gives the classification of American Air Masses, now includes the general International Classification following Bergeron. This change is in conformity with the desirable trend toward the adoption of a standard International System of weather reporting for synoptic, climatological, and comparative purposes. The discussion of Polar Air Masses in winter and their modification to the transitional stages has been expanded to include the findings of later analyses of synoptic weather charts based on the increased aerological data which has become available in the past few years.

The collection of weather maps and cross-sections along with the explanatory notes accompanying them is extremely interesting and instructive. Synoptic weather charts depicting a typical summer weather map, dust storm conditions, cold waves, flood rains, and aircraft icing conditions are given. The cross-sections of fronts during icing conditions by E. J. Minser and Bergeron's model of the warm-front type occlusion including a three-dimensional picture of the warm-front occlusion are recommended for close study by anyone who is interested in meteorology or aviation.

H. T. ORVILLE
U.S. Navy

Aeroplane Design, by E. W. C. WILKINS; Charles Griffin and Co., Ltd., London, 1937; 318 pages, 20s.

This book attempts to cover all phases of airplane design, from elementary aerodynamics to detail design of fittings, but the volume is far too small to allow adequate treatment of such a wide variety of subjects. It might have been better to title the book "Notes on Airplane Design." Many important items are treated sketchily and incompletely, even though they are in the nature of surveys. On the other hand many subjects are given much more space than their relative importance justifies. Particularly is this evident in the last chapter which consists largely of tables and data for allowable loads on ball bearings.

The author makes no mention of the subject of distribution of loads into the structure of the airplane, and this failure to bridge the gap between applied aerodynamics and applied strength of materials is one of the major weaknesses of the book, greatly restricting its suitability for student use.

The first two chapters deal with a brief history of aeronautics and a discussion of the types and component parts of heavier-than-air craft. The discussion of unorthodox types is limited to the helicopter and the autogyro. The material on conventional airplanes would have been improved by the addition of illustrations of modern commercial airplanes, to the exclusion of many photographs of similar-looking, fabric-covered, military biplanes.

The next three chapters deal with the mechanics of flight, stability and control, and performance and maneuvers. A few good sketches would have clarified the effect of aspect ratio, and slots and flaps on airfoil characteristics. The material on performance leaves much to be desired since no mention is made of controllable pitch propellers or supercharged engines and the curves showing the relationship between available and required power are not typical.

The chapter dealing with flight loads would have been improved by the addition of references to pertinent Air Ministry requirements and a discussion of current British practice regarding flight load determination for controls, control surfaces, flaps,

(*Continued on page 210*)

The Correlation of Boundary Layer Transition Data

JOSEPH BICKNELL, *National Advisory Committee for Aeronautics*

Presented at the Aerodynamics Session, Seventh Annual Meeting, I. Ae. S.
January 27, 1939

ABSTRACT

A method of correlating boundary layer transition data is developed in which the pressure distributions over a majority of airfoils can be reduced to a common basis by means of special parameters. When applied to flight transition data on three airfoil sections, the correlation was fairly good.

INTRODUCTION

WITH the discovery by Jones[1] in England that very extensive laminar boundary layers and correspondingly low values of the profile drag coefficient existed on smooth wings in flight, the entire problem of of the boundary layer has assumed new importance. To how high Reynolds Numbers these low drag values can be maintained in flight, how low the turbulence level in the working section of wind tunnels must be to represent flight conditions, how smooth and fair the wings themselves must be are some of the questions related to and arising from the boundary layer problem. These variables—Reynolds Number, air-stream turbulence, and airfoil finish—all manifest themselves insofar as the profile drag coefficient is concerned, mainly through the position of the point of transition from the laminar to the turbulent boundary layer.

The solution of these problems at the present time requires the testing of each body, at each angle of attack, over a range of Reynolds Number and stream turbulence. The elimination of this experimental work depends on the possibility of establishing general relations between the variables. This paper deals with only a small part of this problem, the attempt to reduce the transition point location for different bodies at different angles of attack to one parameter and to determine its variation with Reynolds Number.

CORRELATION BASED ON CERTAIN LOCAL PARAMETERS

Until a short time ago it was assumed that transition would be determined by parameters based wholly on average conditions at the transition point, regardless of the previous history of the boundary layer.

Jones,[1] in an attempt to coordinate the data obtained in flight on the basis of certain local parameters, was not very successful. He remarks, "These observations support the conclusion previously drawn from the flight experiments, that the conditions which lead to transition cannot be expressed solely in terms of the mean values of quantities in the immediate neighborhood of the transition point itself."

It was pointed out by Jacobs (discussion of reference 1), however, that the parameters used by Jones may not have been the most appropriate. Although Pohlhausen's λ, used as the non-dimensional pressure gradient, also represents the boundary layer profile in a region of negative or zero pressure gradient, its significance in a region of positive pressure gradient is doubtful. Nearly all of Jones's transition points fall in this region.

Tests made by Becker of the N.A.C.A. (report to be published) in an attempted coordination on the basis of certain local conditions confirm Jones's conclusion: that, in the general case, such coordination by parameters based on local mean values is not possible. The lack of success of correlating transition data on this basis prompted a search for a method that would take into account the history of the boundary layer up to the transition point.

CORRELATION BASED ON PREVIOUS HISTORY

The fact that the transition point location for a given body placed in a given air stream at a given attitude is a function of Reynolds Number provides a starting point for a method based on the previous history of the laminar boundary layer.

Since the shape and the attitude of a body are characterized by the pressure distribution over the body, the first statement may be modified. The transition point location for a given pressure distribution is a function of Reynolds Number, except for curvature effects, which will be treated later.

As pointed out by von Kármán and Millikan,[2] the shape of the laminar boundary layer velocity profile at any point is determined by the pressure distribution from the stagnation point to the point in question. At corresponding points on two geometrically similar pressure distributions, the boundary layer profiles are geometrically similar; their scale is a simple function of the Reynolds Numbers based on corresponding lengths and velocities.

From this point, the method can best be developed by application to a particular case. Fig. 1 is the distribution of velocity just outside the boundary layer along the upper surface of a profile very nearly the N-22 at a

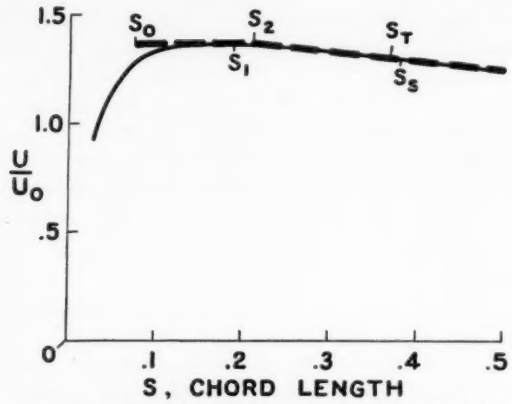


FIG. 1. Velocity distribution along upper surface of a profile very nearly the N-22 at a lift coefficient of 0.44 and linear approximations for the velocity distribution. U/U_0 is the ratio of velocity just outside the boundary layer to stream velocity; S is measured along the surface from the stagnation point.

The symbols are as follows: S_0, leading edge of equivalent flat plate; S_1, point of maximum velocity; S_2, point of application of linear velocity gradient; S_T, measured transition point; S_S, computed laminar separation point.

lift coefficient of 0.44. The velocity distribution is used rather than the pressure distribution because it is more suitable for computations of the laminar boundary layer. All distances are measured along the airfoil surface from the stagnation point.

The method developed by von Doenhoff[3] of estimating the position of the laminar separation point is applied to this velocity distribution. Its basis is the following: At the point of maximum velocity, the pressure gradient is zero and the boundary layer profile is very nearly the same as that for a flat plate; i.e., the Blasius distribution. Insofar as the boundary layer at this point is concerned, then, it might have developed along a flat plate of suitable length instead of along the airfoil surface from the stagnation point to the point of maximum velocity. von Doenhoff has given a method of estimating the equivalent flat-plate length. Downstream of the point of maximum velocity, the best linear approximation to the velocity distribution is made. For correlating transition data, this approximation need be good only as far as the transition point.

The velocity distribution along the equivalent flat plate and the linear velocity gradient approximation are shown by the dashed lines in Fig. 1. The percentage decrease in velocity in a distance equal to the equivalent flat-plate length determines the separation point, denoted by S_S in Fig. 1.

In replacing the experimental velocity distribution by the simplified linear one, the point of peak velocity S_1 is moved downstream slightly to S_2, the point of application of the linear gradient. This movement is usually but a small part of the distance to the laminar separation point and is considered unimportant.

For all velocity distributions to which these approximations would apply, it is evident that at S_2, the boundary layer profiles are all nearly the same shape, that is, nearly the Blasius distribution for a flat plate. At the laminar separation point, their slopes are all zero at the wall; and, for usual velocity distributions along the surface, their shapes are not far different. These observations suggest using the distance S_2 to the separation point S_S as the basis of a new comparison parameter. At given percentages of the distance from S_2 to S_S, the laminar boundary layer profiles for different velocity distributions along the surface may be nearly enough the same shape so that these distributions can be considered to have the same history with respect to this parameter, even though they did not have it with respect to distances measured along the surface.

Just as the transition point referred to chord position is a function of Reynolds Number for a given pressure distribution, so the location in percentage distance from S_2 to S_S may be expected to be a function of Reynolds Number, i.e., $S^* = (S_T - S_2)/(S_S - S_2)$ is a function of Reynolds Number. Positions with respect to the stagnation point have disappeared, as they must if various shapes of velocity distribution are to be reduced to a common basis.

The next step is to define a suitable Reynolds Number. The one decided upon is based on the distance from S_0, the leading edge of the equivalent flat plate, to the laminar separation point S_S. The velocity is taken as the average over the distance S_0 to S_S.

$$R^* = (S_S - S_0)\overline{U}_{(S_0 \text{ to } S_S)}/\nu$$

This method of correlating transition data has been applied to N.A.C.A. flight tests (report in preparation) on a wing of nearly N-22 section and on a wing of nearly N.A.C.A. 2415 section, as well as to some flight tests reported by Jones[1] (the tests for which the velocity distributions along the wing are given). Typical velocity distributions of these tests are shown in Fig. 2, the transition points being marked by ticks.

In Fig. 3 are plotted the results after correlation on the basis of the parameters outlined here. While there is still some scatter of the experimental points, a general relation is defined between Reynolds Number and position of the transition point. At an R^* near 1,400,000, the transition point is near the laminar separation point. As R^* increases, the transition point moves toward the point of maximum velocity at a decreasing rate.

Owing to the approximations used, the computed laminar separation point moves to infinity as the transition point approaches the point of maximum velocity. The method thus becomes unsuitable when transition moves forward to a point near that of maximum velocity.

Some scatter in the experimental points probably arises in the computation of the laminar separation point, which varies somewhat depending on the fairing of the experimental points defining the velocity distribution along the surface of the airfoil. Possible errors

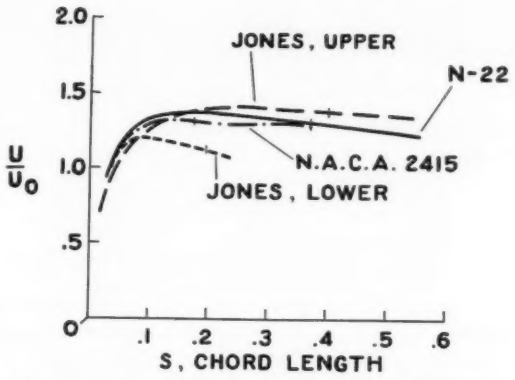


FIG. 2. Typical velocity distributions of flight transition data. The ticks indicate the experimental transition points.

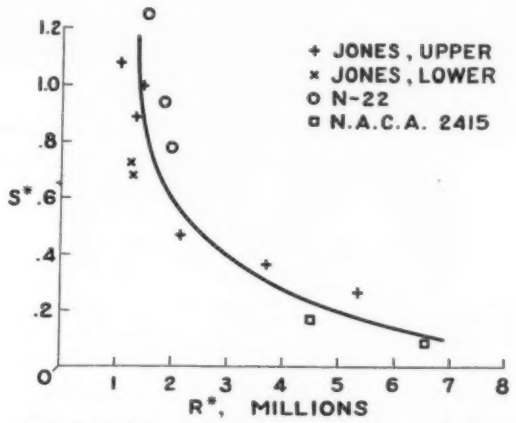


FIG. 3. Flight transition data correlated on basis of new parameters.

are introduced by neglecting the effects of curvature of the different airfoils at the transition point. An estimation has been made of the change in Reynolds Number that would be equivalent to the stabilizing curvature of the N-22 wing section, as compared with a flat plate.[4] The curvature should correspond approximately to a 2 percent increase in Reynolds Number, which is well within the accuracy of this method.

While the linear approximation to the velocity distribution in the region downstream of the maximum velocity point at first seems quite severe, by far the majority of cases of conventional airfoils in the range of flight angles of attack lie within its scope. That the transition points occur downstream of the point of maximum velocity is another restriction of the method. It has been found that, on conventional airfoils in flight and in smooth tunnels, the transition point lies in this region even up to moderate values of flight Reynolds Number.

As first developed, this method embraced the possibility of including another parameter, turbulence. A family of R^* against S^* curves would be found, each curve relating to a particular value of the Taylor turbulence parameter, so that corresponding values of S^* would occur at decreasing values of R^* as the turbulence parameter increased. Application to tunnel data indicated that on the whole, this deduction was true, but some conflicting data indicated that this branch must be investigated more thoroughly before any conclusions may be drawn. Possibly, as Dryden[5] points out, the mechanism of transition in turbulence-free streams (flight) may not be the same as that in turbulent streams. The present analysis might therefore become inadequate for the purposes of correlating turbulence effects.

In conclusion, although the method must be considered to have only a limited range of application, it has been shown that boundary layer transition data from several flight tests can be correlated with a fair degree of success.

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Flight Altitude Control

CHARLES H. COLVIN, *Kollsman Instrument Company*

Presented at the Air Transport Meeting of the I. Ae. S., Chicago
November 19, 1938

THE control of flight altitudes in air transport requires the solution of two separate but closely related problems: (1) the maintenance of adequate vertical clearance between two or more airplanes, and (2) the maintenance of vertical clearance between the airplane and the ground. The latter problem comprises (a) maintenance of sufficient distance between the airplane and the ground while in flight, and (b) reduction of this distance to zero in landing.

A third problem of flight altitude control is the accurate maintenance of true altitude in aerial photographic mapping. As this is not of concern in air transport operation its consideration is relegated to an appendix.

In this paper the flight altitude control problem is considered only in relation to those items of equipment now generally used in air transport operation, namely: the Sensitive Altimeter and Free Air Thermometer on the airplane, the Barometer and Thermometer at the airport, and the radio communication facilities connecting airplane and airport.

Although it is generally well known, it is important to emphasize the fact that an altimeter (Fig. 1) is not, actually, an indicator of altitude, but is an absolute pressure gage the scale of which is graduated in units of altitude in accordance with a formula* based upon certain "standard" conditions.

Pressure values for use in calibrating an altimeter are determined from this formula by assuming that the sea level pressure is 29.921 in. of mercury, that the temperature at sea level is 15°C. (59°F.), and that the temperature decreases with increase of altitude at the rate of 1.9812°C. (3.566°F.) per thousand feet.

Altimeters have barometric pressure scales which may be set to any pressure from approximately 28 to 31 in. of mercury. That is, with the altimeter at sea level the hands may be made to read zero for any pressure within this range. Similarly, with the altimeter at any known altitude the hands may be made to read that altitude.

A free air thermometer (Fig. 2) is a temperature indicator the responsive element of which is located at some point on the airplane structure where it is exposed to the air, the indicating element being in the pilot's cockpit.

Station thermometers and barometers are well known. A type of station barometer (Fig. 3) which is substantially the same as the sensitive altimeter used on the airplane is a convenience, though not a necessity, in determining pressure values.

Before considering the use of the altimeter in flight altitude control it is important to have a clear idea of the relation between its readings and the true altitude. Assuming that the instrument has no scale errors but is giving a correct indication of the existing pressure, in terms of altitude in accordance with the relationship established by the standard formula: if the barometric pressure at sea level is 29.92, the temperature at sea level is 15°C., the temperature gradient is 1.98°C. per thousand feet, and the altimeter's barometric scale is set to 29.92, the indication of the instrument will be the true altitude. Under no other set of conditions will the indication of an altimeter be the true altitude, except at one place—that for which its barometric scale is set to give the true altitude—and at that place only so long as the barometric pressure does not change.

However, determination of true altitude from indicated altitude is simple and the accuracy of the resulting true altitude value depends only on the accuracy of the pressure and temperature information available. The relation between true and indicated altitudes is given by the formula

$$H_t = (T_{ma}/T_{ms})(H_i - H_0) + H_0$$

where

H_t is the true altitude above sea level,
H_i is the indicated altitude above sea level,
H_0 is the elevation of the airport upon which the barometric setting is based,
T_{ma} is the actual mean temperature, in degrees absolute, of the air between altitude H_t and altitude H_0,
T_{ms} is the standard mean temperature, in degrees absolute, of the air between altitude H_t and altitude H_0.

* This formula is

$$H = 221.152\ T_{ma} \log (P_0/P) + H_0$$

where H is the altitude in feet above sea level, T_{ma} is the mean temperature (in degrees Centigrade absolute) of the air from the ground to the altitude H, P is the pressure at altitude H, P_0 is the pressure at the ground, and H_0 is the altitude of the ground over sea level.

FIG. 1.

FIG 2.

FIG. 3.

Conversion of indicated to true altitude is best illustrated by an example. Assume that the known data are:

Elevation of the airport, 1955 feet.
Barometric setting of a station barometer or sensitive altimeter at the airport to produce an altitude indication of 1955 ft., 29.74 in.
Temperature at the airport, 5°C.
Free air temperature on the airplane, −9°C.
Indication of the airplane's altimeter when its barometric scale is set to 29.74, 9000 feet.

Putting the known data into the formula (the value of T_{ms} being taken from the Standard Atmosphere Tables and that of T_{ma} as the average of the temperatures on the airplane and at the airport),

$$H_t = (271/277)(9000 - 1955) + 1955$$

and the true altitude is found to be 8847 feet. This is correct if there is a smooth temperature gradient between the ground and the airplane. If there is a temperature inversion, that is, if the mean temperature is higher than the average of the airplane and airport temperatures, the calculated true altitude will be slightly less than the actual altitude.

Approximate results are obtainable by the use of a simpler formula which disregards the temperature at the airport. This formula is:

$$H_t = (T_a/T_s)(H_i - H_0) + H_0$$

where

T_a is the actual air temperature, in degrees absolute, at the flight altitude
T_s is the standard air temperature, in degrees absolute, at the flight altitude.

The "true" altitude as determined by this formula is slightly less than that given by the more precise formula if a normal temperature gradient exists. In the above example it gives a "true" altitude of 8843 feet.

The above calculations may be made by the use of Luckey, Dalton or Kollsman computers, or graphically, by the use of nomographs, or for any given airport as a base, may be pre-calculated in terms of free air temperature.

Proceeding now to the specific problems, the maintenance of vertical distance between airplanes may be based upon indicated altitudes or true altitudes, or directly on pressures, disregarding altitude units entirely.

Considering these in reverse order, all airplanes might carry an absolute pressure gage and flight levels might be established at specific pressure levels instead of in terms of altitude as at present. Instead of requiring westbound flights to be made at even thousand feet, for example, the C.A.R. might require them to be made at pressures of even inches of mercury. Advantages of this system would be the use of absolute values independent of any ground reference, which might be inaccurately set on the altimeter of one of the airplanes. Disadvantages would be the need of

TABLE 1

Airway: Ellensburg–Seattle
Control Station: Seattle
Minimum permissible true altitude: 8700 ft.

Indicated Altitude, ft.	At °C.	At °F.
11,000	−59	−74
10,700	−53	−63
10,200	−42	−44
10,000	−37	−35
9,700	−30	−22
9,200	−17	+ 1
9,000	−11	+12
8,700	− 2	+28

carrying an additional instrument, the fact that while one inch of mercury corresponds to less than 900 feet at sea level it represents more than 1300 feet at 12,000, and the fact that there would be no relation between altitudes maintained by this system and altitudes necessary for ground clearance. A variant of this system would be the use of an altimeter permanently set for a pressure base of 29.92.

Establishing vertical clearance between airplanes in terms of either indicated or true altitude requires the use of the same pressure base by all aircraft flying on the same route section. A spacing of 1000 feet of indicated altitude would correspond to more than 1000 feet of actual vertical separation when air temperatures are high, and to less than 1000 feet of actual spacing at low temperatures. Extremely low temperatures might reduce the actual clearance by 20 percent, or to 800 feet.

The use of true altitudes has the advantage of assuring actual clearances of 1000 feet, or of such other distance as may be desired, while having the disadvantage of requiring calculations to convert indicated to true altitude, with the possibility of error in the conversion.

The use of indicated altitudes has the advantage of requiring no calculations and the disadvantage of maintaining vertical spacing which is variable with temperature.

Referring now to the problem of maintenance of clearance over ground obstacles, it is obvious that true altitudes must be used rather than indicated altitudes. It has been pointed out that true altitudes may be as much as 20 percent less than indicated altitudes at extremely low temperatures. Hence, an indicated altitude of 15,000 feet might provide no clearance over a mountain 12,000 feet high.

There are several methods of attacking this problem:

(1) The pilot might be required to fly high enough so that even though his true altitude were 20 percent less than his indicated altitude, he would still clear all obstacles. This method would require maintenance of altitudes which are normally much higher than necessary.

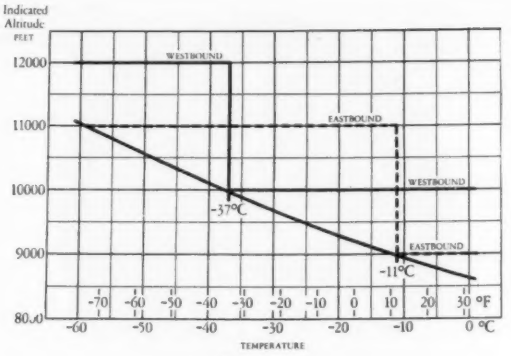

FIG. 4.

(2) The pilot might be given instructions as to the minimum true altitude to be maintained on each route section and provided with the necessary computers for converting indicated to true altitude. The disadvantages of this method are obvious, as a large burden of computation is thrown on the pilot when the weather is bad—at a time when he is least prepared to concentrate upon it.

(3) A third method is to provide the pilot with a precalculated table or graph for each route section, in which indicated altitude is charted against temperature to establish a "deadline" below which he may not go.

Such a table is shown in Table 1, with the corresponding graph in Fig. 4. This is prepared for the airway section from Seattle to Ellensburg, with altimeter barometric scales set to the kollsman number* as transmitted from Seattle. The minimum permissible true altitude for this route section is 8700 feet. The curve represents the indicated altitude required at each air temperature (measured on the airplane) to maintain 8700 feet true altitude.

The normal eastbound flight altitude is 9000 feet indicated. This indicated altitude may be maintained only so long as the temperature remains above −11°C. (12°F.). For lower temperatures the pilot must go up to the 11,000 foot (indicated) level, except when an emergency warrants a departure from the C.A.R. flight altitudes. In such case, the curve establishes the minimum permissible indicated altitude for every temperature.

Similarly, for westbound flights the pilot normally maintains a 10,000 foot (indicated) level unless the temperature goes below −37°C. (−34°F.), in which case he climbs to the 12,000 foot (indicated) level. As on eastbound flights the minimum permissible indicated altitude for each temperature is set by the curve.

* This value is also called "altimeter sea level pressure," "indicated sea level pressure," "local equivalent sea level pressure," and "Standard Atmosphere sea level pressure." It is called "kollsman number" here in order to avoid confusion, since this designation is universally used in airways radio broadcasts.

The use of the sensitive altimeter in landing requires that its barometric scale be set to the kollsman number of the airport. This technique is so well known that discussion of it here is unnecessary.

Conclusions

Both problems—maintenance of clearance between airplanes and maintenance of clearance over the ground—are solved by observing the following rules:

(1) While on a given route section all pilots must keep the barometric scales of their altimeters set to the same kollsman number, as transmitted by the station controlling that route section.

(2) Except in emergencies, pilots must fly at the odd or even thousand foot altitudes prescribed by the C.A.R., as *indicated* by their altimeters. A permissible minimum temperature is associated with each flight level. At lower temperatures the pilot must go to the next higher flight level.

(3) In emergencies the pilot must fly at an *indicated* altitude no lower than that established by the altitude-temperature "deadline" on the chart for that route section.

Advantages of this system of flight altitude control are:

(1) The same instruments and methods are used for maintaining vertical separation of airplanes as for maintaining clearance over the ground.

(2) No instrument equipment is required in addition to that now regularly carried.

(3) The barometric scale of the altimeter is always set to the correct value for landing on the control airport.

Appendix

Control of Flight Altitude in Aerial Mapping

For photographic work it is necessary to determine the correct indicated altitude to correspond to a desired true altitude. The most useful form of the altitude-temperature equation is

$$T_{ma} = T_{ms}(H_t - H_0)/(H_i - H_0)$$

To avoid the necessity for any but the simplest calculations on the part of the pilot, actual mean temperatures may be pre-calculated for a range of indicated altitudes and the results plotted as a curve (Fig. 5).

To take an example, assume that

H_t, the desired true altitude, is 17,000 feet above sea level, and

H_0, the altitude of the control station, is 3000 feet above sea level.

T_{ms} cannot be determined directly from the above data, since it depends upon the *indicated* altitude, not upon the true altitude. However, to locate each point on the proposed curve, an indicated altitude must be assumed, and the value of T_{ms} for this indicated altitude may be taken from the Standard Atmosphere Tables[1] as that corresponding to an altitude of $H_i + H_0$ (since T_{ms} is approximately the same for an air column extending from H_0 to H_t as for the air column from sea level to $H_t + H_0$).

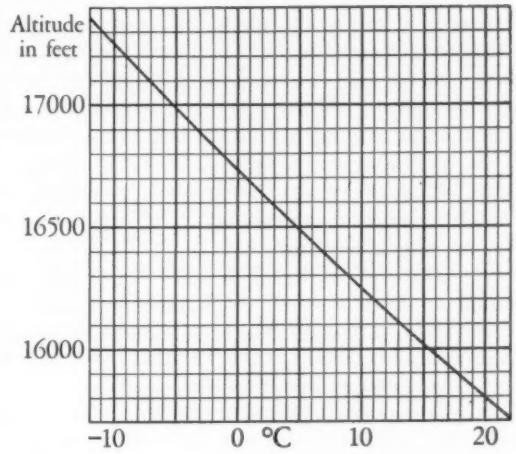

Fig. 5.

For an indicated altitude of 16,000 feet, therefore, the value of T_{ms} is −4.3°C. or 268.7°C. abs. (the value found in the Standard Atmosphere Tables for 16,000 + 3000 = 19,000 ft.).

Putting this value in the above equation,

$$T_{ma} = 289.4°\text{C. abs.} = 16.4°\text{C.}$$

Similar calculations for other assumed indicated altitudes from 15,700 to 17,400 feet give the mean temperatures which are plotted in Fig. 5.

For example, suppose the pilot reads the temperature for every thousand feet above the station up to an indicated altitude of 15,500 feet and finds that the mean average of these temperatures is 18°C. Referring to the curve, the correct indicated altitude is seen to be 15,890 feet.

The pilot's work may be still further reduced by making allowance for known calibration errors of the altimeter when plotting the curve, thus relieving him of the necessity for applying any corrections.

Determination of "Altimeter Sea Level Pressure"

The figure at which the barometric scale of an altimeter is to be set is known as the altimeter sea level pressure, or, more simply, as the kollsman number. It may be determined from a mercury or aneroid barometer or from a Kollsman Station Barometer.

If a mercury barometer is used, its readings must be corrected for (a) scale errors, (b) gravity, and (c)

[1] Brombacher, W. G., *Altitude-Pressure Tables Based on the United States Standard Atmosphere*, N.A.C.A. Technical Report No. 538.

temperature, to obtain the *station pressure.* If the barometer is located higher (or lower) than the actual altitude of the field runways, the station pressure must be converted to *field pressure.* The kollsman number must then be calculated from the field pressure figure.

The barometer corrections are made as follows:

(a) Scale errors are shown on a correction card accompanying each barometer. They are to be applied as directed on the card.

(b) Gravity errors result from a location of a barometer other than at sea level and 45° latitude. The gravity correction factor is a constant for any given location. Data for this correction will be found in the Smithsonian Meteorological Tables.

(c) Temperature errors result from the unequal expansion of the mercury and the brass or aluminum scale. Correction tables will be found in most laboratory handbooks.

The barometer reading, after application of these corrections, is the *station pressure.* This value is given directly by an aneroid barometer, after correction for any scale error shown on the instrument's correction card.

The field pressure is different from the station pressure by a constant whose value depends upon the distance the barometer is above (or below) the level of the field runway. To determine this constant it is necessary to know (a) the altitude of the station (that is, of the barometer itself) above sea level, and (b) the altitude of the field runway above sea level. This pressure difference is found as follows:

(1) Determine the Standard Atmosphere pressure for the station altitude, from the Standard Atmosphere Altitude-Pressure Tables.

(2) Determine the Standard Atmosphere pressure for the field altitude, from the same Tables.

(3) Subtract (1) from (2). This is the constant to be added to the station pressure to give the field pressure. It needs to be computed only once for any station and field, if the altitude difference is not greater than 100 feet.

Having the field pressure, the kollsman number is found as follows:

(1) Determine the Standard Atmosphere altitude for the field pressure, from the Standard Atmosphere Tables.

(2) Subtract the field altitude from (1).

(3) Determine the Standard Atmosphere pressure for (2), from the same Tables. This is the kollsman number.

The procedure is best illustrated by an example. Suppose (a) the station altitude is 4248 feet, and (b) the field altitude is 4227 feet. Referring to the Standard Atmosphere Altitude-Pressure Tables, the difference between the pressures corresponding to the two altitudes is 0.02 in. Hg. This value (0.02) is the constant to be added to the station pressure to give the field pressure. If the station pressure is 25.63 the field presssure is 25.65.

Proceeding with the example, (1) the altitude for 25.65 in. is 4199 feet, (2) 4199 − 4227 = −28 feet, and (3) the pressure for −28 feet is 29.95 in. Hg. Thus "kollsman 29.95" is to be transmitted by radio to the airplane.

Using the same system, but substituting a Kollsman Station Barometer for the mercury or aneroid barometer, the procedure is as follows: Set the hands of the Kollsman Station Barometer to the station altitude (making allowance for any scale error) and read the barometric scale or setting markers. Transmit this figure to the airplane.

Book Reviews

(*Continued from page 202*)

and fuselages. The chapter on construction devotes little space to modern types.

In the chapter dealing with the strength of materials some phases of elementary beam theory are treated rather completely although the subject of application of strength of materials to airplane structures might have been emphasized.

Brief chapters are devoted to materials and their properties, and protective processes and heat treatment.

In the chapter on considerations of strength in airplane structures, there is no material on combinations of stresses such as bending and torsion, and in view of the importance of columns it is felt that the author should have clarified British practice on this subject with typical curves of allowable stress *versus* slenderness ratio.

Although the book contains no consolidated bibliography there is a list of references at the end of most of the chapters. These lists consist almost entirely of R. and M.'s, and constitute a valuable part of the book, even though no material published subsequent to 1935, is included.

HOWARD W. BARLOW
New York University

Practical Aeronautical Engineering, by WILLIS L. NYE, Aviation Press, San Francisco, 1938; 187 pages, $4.00. (Loose-leaf lithographed.)

This book is designed to "serve as an intermediate text for the student engineer actively interested in modern airplane construction." It is intended as a continuation for the student who has digested "the Cadet System" by Leslie Thorpe (same publisher.) The subjects covered include aircraft design procedure, airfoil data, aerodynamic factors in design, parasite resistance data, stability, control and control surfaces, propellers, aircraft engineers and installation problems, landing gears, performance calculations, high performance aircraft, economics of aircraft structure, and weight control. There are 164 excellent figures and the data compiled in 145 tables should find ready use.

In a subject that is changing rapidly, a book of this type requires constant revision. For instance the tables in which data for contemporary aircraft are given, figures for the DC-3 should be included. The chapter on landing gear could well be expanded to include tricycle as well as conventional landing gear.

Combating Corrosion in Design and Construction

RALPH S. BARNABY, *U.S. Navy*

Presented at the Structures Session, Seventh Annual Meeting, I. Ae. S.
January 25, 1939

SUMMARY

A study of the maintenance of large aluminum alloy flying boats makes it clear that corrosion is still a major problem. This corrosion is not general, but in isolated spots and associated with unsealed crevices, undrained pockets, and dissimilar materials. If a reasonable service life is to be obtained, corrosion prevention must start on the drafting board, and continue throughout the design and construction of the airplane. The rules are: (1) fill the crevices; (2) drain the pockets; (3) keep dissimilar materials apart.

INTRODUCTION

DURING the past few months millions of dollars have been going into the construction of huge air liners for trans-oceanic service, and it is fair to suppose that those behind these dollars are expecting a reasonable return on their money. The question is, "Are they going to get it?" A fair return, naturally depends on many things, but it is proposed to consider here only one which pertains to the airplanes themselves. Here two important and correlated factors loom—maintenance cost and service life, and hovering above them, the spectre, corrosion.

With a view to making some concrete recommendations relative to corrosion for use as a guide to designers, and as a basis for shop procedure and inspection, an attempt has been made to analyze the types of corrosion found, to classify their causes, and to consider means for their prevention.

TYPES AND CAUSES OF CORROSION

In general it may be stated that no new types or causes of corrosion have been found. In all cases corrosion has been the result of violations of principles and practices which should be familiar to all manufacturers of seaplanes, and particularly to those who have worked to Navy Specifications. It is encouraging that the corrosion found is not general, but is confined to isolated spots. This indicates that the methods of protection probably are satisfactory fundamentally, but that they are not taken seriously enough, or not carried out thoroughly. Nothing has been found to challenge the axiom that if moisture can be kept away from the parts, there will be no corrosion.

Practically all corrosion is found in conjunction with one of the three following situations:

(1) Unsealed crevices.

(2) Undrained pockets.

(3) Dissimilar materials in contact with aluminum alloy.

UNSEALED CREVICES

Included in the first group are contact surfaces such as lap-joints, attached fittings, reinforcing plates, and members, whether riveted, bolted, screwed, or welded together. This group and dissimilar materials, group 3, or a combination of the two probably accounts for most cases of corrosion.

To begin with it may be stated that if there is a crevice or opening between the surfaces, water will get in and corrosion will result. It matters not that both parts are of the same aluminum alloy, that they have received all the prescribed preparations—anodic treatment, primer, coats of paint—that there may be an impregnated gasket of some kind in the joint, or that the joint may have been made up with wet paint. None of the practices now employed prevent crevices in all cases.

A few examples will help to demonstrate the point. Fig. 1 shows a portion of the lower chord member of a compression rib in the lower wing of a twin-engine sesquiplane flying boat. This member was made up of two heat-treated aluminum alloy (17ST) angles riveted back to back. Just why a T section was not used is not apparent, but in any case, these angles had been anodically treated, primed, riveted together with wet primer on the contact surfaces, and finally, the whole rib finished with the prescribed finish coatings. Nevertheless, in practically all airplanes of this type, corrosion developed in the joint as shown in Fig. 1. In many cases it progressed to such an extent before discovery that the corrosion products pushed the angles apart between rivets as much as a half inch, sometimes popping off the rivet heads as well These wings were fabric-covered and undoubtedly picked up much salt spray in take-offs and landings, but it is also a fact that the fabric was removed every 12 months and this condition would develop within that time.

Corrosion in the contact surfaces between plating and stringers, frames, bulkheads, and other reinforcing members, all set up in wet primer, is common. Fig. 2 shows a common failure of this type. Moisture has settled between the hull plating and the stringers and has broken the protective coatings, resulting in rapid

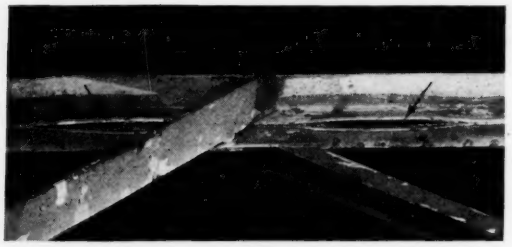

FIG. 1. Lower chord of drag strut of lower wing of flying boat. Corrosion products, removed before photographing, have pushed the contact flanges apart.

FIG. 2. Interior view of flying boat hull bottom, showing corrosion under stringers.

and serious corrosion to both. In some such cases the damage was great enough to necessitate renewing sections of both plating and stringers. This airplane had been in service less than a year.

UNDRAINED POCKETS

The second group includes all places where water can stand in contact with the structure. Of course, in places where this results in water standing in contact with joints and fastenings, it is just an aggravated group 1 case. However, there are many cases of corrosion where no joints are present and where it is the result of standing water penetrating the protective coatings and attacking the metal underneath. Channels with flanges up are common examples. It is a well-known fact that finishes used are not water-proof, only water-resistant. If water stays in contact with them long enough, it will penetrate, and corrosion will result.

There is hardly a seaplane that comes in for maintenance or overhaul which does not show some spots of deterioration of this sort.

DISSIMILAR MATERIALS

The third group may be divided into two subgroups: (a) dissimilar metals in contact with aluminum alloy, and (b) non-metallic contact, where materials such as wood, fabric, felt, or other water-absorbing substances are in contact with aluminum alloy.

It is common knowledge that when two different metals are near enough together for the gap to be bridged by an electrolyte, electrolytic action results,

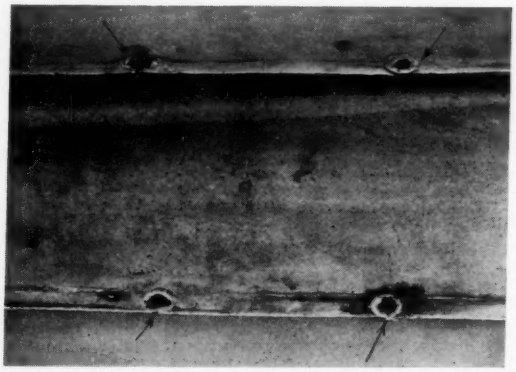

FIG. 3. Section of aluminum alloy fairing, showing corrosion caused by use of copper grommets.

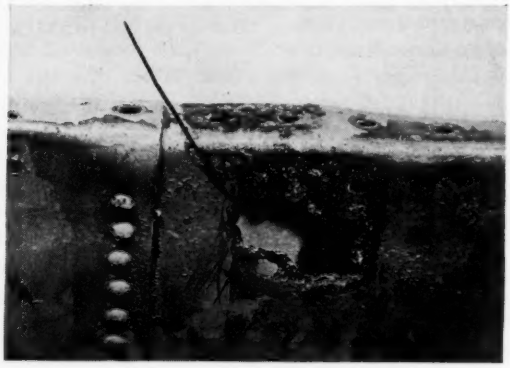

FIG. 4. Corrosion of aluminum alloy sheet under steel fitting.

the speed and violence of the action depending on the relative positions of the metals on the electromotive list. While the copper-rich alloys are probably worse than others, the fact is that practically all metals used in aircraft will react with aluminum alloy to the detriment of the aluminum. In seaplanes there is no lack of electrolyte, in the form of salt water resulting from leakage, spray, and salt air. In addition to the damage done directly by these items, they leave a salt deposit throughout the structure to convert rainwater and condensed moisture into active reagents. In Fig. 3 is shown what happened where brass grommets were used on some aluminum alloy cowling. Fig. 4 is an example of corrosion resulting from use of a steel fitting in contact with aluminum alloy. In this case the steel had been cadmium plated and primed and an insulating gasket was used.

It is not necessary that the dissimilar metals be parts of the airplane at all. Fig. 5 shows a hole which suddenly appeared in the fairing on a patrol plane less than a year old. Investigation showed that a steel bolt had dropped down in the crevice between the fairing and the hull plating. This pocket was poorly drained, and electrolytic corrosion started immediately. The hull plating was similarly affected, but being of

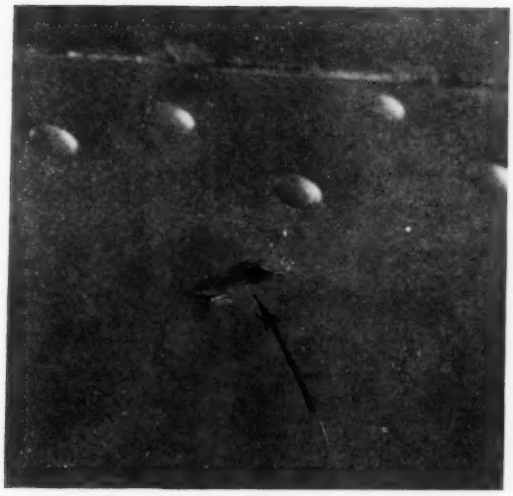

FIG. 5. Hole corroded through plating, resulting from a bolt being dropped and lodging in a crevice under plating.

FIG. 6. Corrosion in interior of wing-tip float resulting from presence of particles of steel wool embedded in the paint.

heavier gage had not corroded completely through when discovered. Fig. 6 shows the beginning of corrosion inside a wing-tip float resulting from bits of steel wool embedded in the paint. This wool had been used, contrary to good practice, to smooth down the priming coat. The finish coats were then applied evidently without cleaning out the float.

With regard to group 3b, moisture-absorbing material in contact with aluminum alloy, it is evident from what has preceded that any agent which can hold moisture in contact with aluminum alloy structure will promote corrosion. In spite of our modern so-called all-metal construction there are many such cases. A very common example (Fig. 7) shows the corrosion under a cork filled bumper pad on the nose of a wing-tip float. Because of incomplete water-excluding impregnation in the fabric strips used in hull and float water-proof joints, corrosion in these joints is common. Fig. 8 is typical.

The next example is put in this class because the gasket material, though not water-absorbent to any appreciable degree, is certainly a "dissimilar material." Any soft gasket material used in the faying surfaces is

FIG. 7. Corrosion under bumper-pad of wing-tip float.

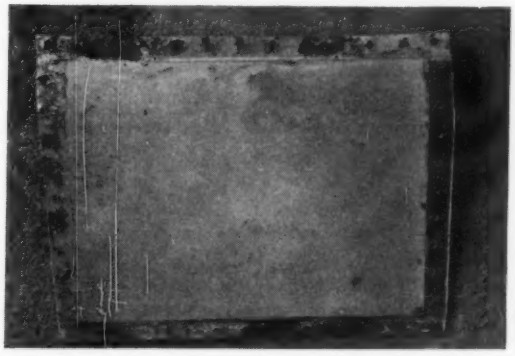

FIG. 8. Flying boat hull plate, showing corrosion resulting from penetration of water into "water-tight" joint.

bound to cause a certain amount of quilting or bulging between fastenings and along free edges. In some cases this bulging is sufficient to form crevices. Fig. 9 shows a failure in the flange of the main wing section of a modern patrol-type flying boat little more than a year old. A careful inspection after removal of the trailing-edge section of the wing showed that corrosion of this type was developing in spots throughout the hundred or more feet of this type joint in each airplane. Fig. 10 shows the general location of the spot illustrated in Fig. 9, and a detail of the joint. These failures are made more serious because the section affected is used for fuel storage.

A chloroprene-base gasket is used in the joints, and the distance from the last row of rivets to the free edge is too great to keep the joint tight at the edge. The

FIG. 9. Corrosion in flange of gasoline-tight joint in flying boat wing structure.

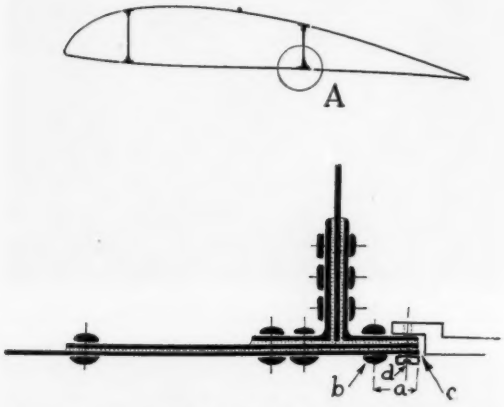

FIG. 10. General location of the joint shown in Fig. 12, and an enlarged section of *A*, the joint in question. Dimension *a* indicates the excessive distance from the last row of rivets *b* to the free edge *c*. *d* is the securing screw for the removable trailing edge.

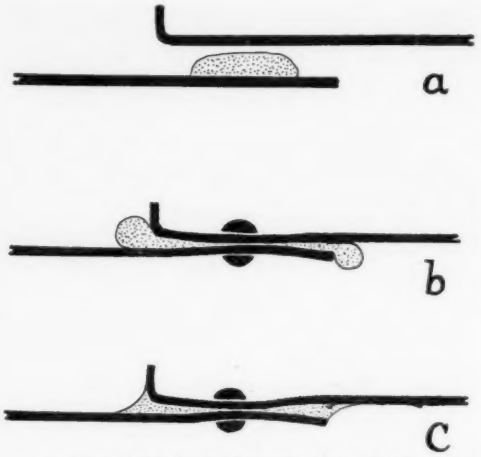

FIG. 11. Steps in making up a joint using seam compound. The distortion of the sheets around the rivet is characteristic though exaggerated in the sketch.

FIG. 12. Results obtained when the compound is applied to a completed joint.

trailing-edge attaching-screws are too far apart and have insufficient clamping power to help much.

A complete redesign of this joint is needed. From the point of view of corrosion-prevention, it is extremely bad practice to have the last row of permanent fastenings so far from the free edge. It is practically impossible to keep such joints tight. This is particularly true where gasket materials are used, because of the resulting distortion of the sheet.

RULES FOR CORROSION PREVENTION

The rules for corrosion prevention can be summed up in one statement, *i.e.*, keep the moisture away. The carrying out of such a program in practice, however, is sometimes difficult, and requires diligent study and care. One encouraging fact is that there is seldom a direct attack on an area of properly treated and finished aluminum alloy unless it is associated with one of the conditions outlined above, and it occurs only in isolated cases. This lack of general corrosion indicates that the protective coatings used are, for the most part, effective, and that more care is being taken and more accurate control is being exercised to see that the aluminum alloy is correctly heat-treated. In the earlier aircraft a considerable amount of rapid corrosion resulted from non-uniform and improper heat treatment.

First, all crevices must be filled. This means that the sealing of all joints is imperative whether they are structurally designed as "water-tight" joints or not. In general, setting in wet primer is not sufficient, for the materials being worked with are not flat enough—they distort between fastenings leaving crevices greater than the paint can fill. Probably the nearest approach to a perfect seam would be one made up as shown in Fig. 11. (a) The parts, having been properly prepared, drilled, anodized, and primed, a generous amount of a suitable plastic seam compound is laid along the joint. (b) The parts are drawn together with the fastenings, whether rivets, bolts or screws, which have been dipped in primer just before driving. The warping of the sheet shown in the sketch, while exaggerated, is typical. (c) The excess compound is cleaned away leaving generous fillets along the free edges.

Experimental compounds of this type are now under test.

Another and less positive protection, but one which could be applied in maintenance of airplanes already constructed, would be to attempt to seal up the joints by paying compound into them. Fig. 12 shows a typical section of such a joint. There is almost certain to be a pocket at (a) and if the seal should fail at any point, moisture would enter.

The draining of all corners, pockets, and troughs to prevent water standing in contact with the structure requires careful study and planning by the designer.

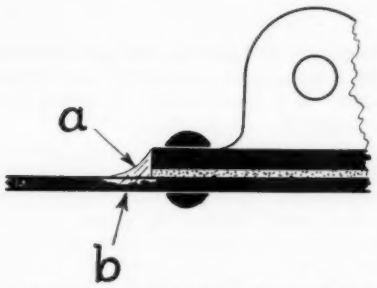

FIG. 13. Sketch showing the inadequacy of insulation furnished by placing a thin gasket under a steel fitting secured to an aluminum plate. *a* indicates the water film bridging the gasket, and *b* the resulting pit of corrosion.

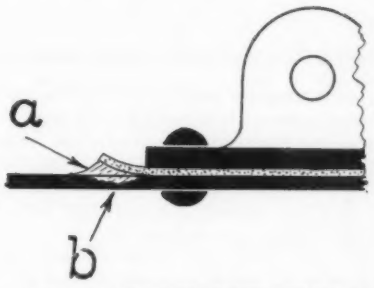

FIG. 14. An unsatisfactory method of coping with the condition shown in Fig. 13. The thin gasket has curled up allowing water to lie underneath *a*, resulting in a corrosion pit *b*.

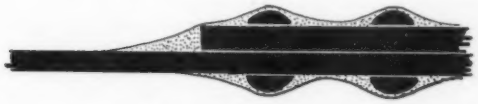

FIG. 15. Use of metal spray to seal permanent joints.

Any water that gets inside the airplane should flow either to an overboard drain or to a suitable and accessible sump, from which it may be pumped. In this sump it is well to keep a small bag of sodium chromate crystals. This will serve to render the water which accumulates in the sump between pumpings less corrosive.

The fact that only a very little water is necessary to start trouble cannot be too strongly stressed. The bulb along the free edge of the horizontal flange of an extruded bulb section, the flanged up edge of a strip of sheet, either of these is sufficient to hold all the water necessary. The modern all-metal airplanes, flying at varying altitudes and temperatures sweat considerably. This condensate combined with the salts deposited by sea air is sufficient for the purpose.

With dissimilar metals the best solution is to eliminate them. Where this is not possible, and there are many places where it is not, the only solution is to insulate and keep moisture away. Insulation by placing a thin gasket of fabric, aluminum foil, or phenol fiber between the two parts is not sufficient. Water can bridge the insulation as shown in Fig. 13, resulting in the corrosion shown. In the past, attempts have been made to prevent this by use of a larger gasket but since the gasket was usually thin and flexible, the free edges did not lie flat on the metal and so formed a crevice to hold water and promote corrosion (Fig. 14). In many cases where a fabric gasket has been used it has not been thoroughly impregnated and so has served as a wick to draw moisture into the joint.

The insulator must be impervious to moisture. It must be large enough to prevent water-bridging of the kind shown in Fig. 13. It must be stiff enough to prevent lifting as shown in Fig. 14. The whole joint must be sealed with some compound to prevent the entrance of moisture.

Similar precautions must be taken with steel bolts and rivets which pass through aluminum alloy. In such cases, particularly along the shank, insulation as discussed above is not practicable. This makes it doubly necessary to keep water away by using compound in the joint, dipping the fastening in primer before inserting, and, where possible, using insulating washers under heads and nuts, and finally filleting all joints and around heads and nuts with compound before the final paint coats.

A method which has been used fairly successfully in the case of large and important structural fittings has been, after the steel fitting was riveted in place, to sand-blast it and the adjacent metal lightly and then metal-spray the whole area with aluminum, building up generous fillets along all seams and around fastenings. The whole was then finished with the approved primer and paint coatings (Fig. 15). This method has been used successfully to prevent corrosion around and under wing-hinge fittings.

Copper and brass should be kept away from aluminum alloy. There have been numerous cases, for instance, of copper fuel lines sagging between supports to rest on some portion of the airplane structure. The author has seen a case where such a condition caused a hole a foot long in a hull bottom.

Moisture-absorbing material, such as unimpregnated fabrics, felts, wood, leather, and the like, should not be used in contact with the structure.

CONCLUSION

The author believes that greater care in the use of the preventative measures given above will practically eliminate corrosion in aluminum alloy aircraft.

Institute Notes

S.A.E. 1939 World Automotive Engineering Congress

Aircraft, aircraft engines, and their fuels will be treated in 18 of the 60 technical papers to be presented at the coast-to-coast 1939 World Automotive Engineering Congress of the Society of Automotive Engineers. The Congress opens May 22nd in New York for a five-day session, will be in Indianapolis May 29th to 30th, in Detroit May 31st to June 2nd, and closes with a three-day session in San Francisco, ending June 8th.

During the New York part of the program, Major R. H. Mayo, director of the Mayo Composite Aircraft Co., Ltd., England, will describe this type of construction, and Otto J. Merkel, a German authority of helicopters, will explain what is new in this field. "Some European Comments on High-Output Automobile and Aero Engines," an analysis of these developments, will be presented by Dr. Ing. W. P. Ricart and Dr. Ing. Sandro Sirtori, Alfa Romeo design engineers from Italy. E. W. Hives, Rolls-Royce, Ltd., England, will discuss British practice in high-output engine developments.

"Transatlantic Airplane Design Problems" will be presented by R. J. Nebesar, Avia, Czechoslovakia; "Flight Testing of Large Transport Airplanes" by E. T. Allen, Stearman Aircraft division, Boeing Airplane Co., "Advantages of Three-Engine Aircraft" by G. Gabrielli, Fiat, Italy; and Dr. Ing. H. Altwicker, I. G. Farbenindustries, Germany, will report on "Use of Magnesium Alloys in European Automobile and Aircraft Industries." "Propeller and Engine Vibration Stress Problems," by Erle Martin, Hamilton Standard Propellers, and other papers on problems in this field are included in the New York meeting.

On June 6th in San Francisco, D. W. Tomlinson, Transcontinental and Western Air, Inc., will present a paper on "Sub-Stratosphere Flying." The next day Arthur Nutt will discuss "Aircraft Engines and Their Lubrication," and F. R. Banks, Ethyl Export Corporation, England, will speak on "European Aero Engines and Their Fuels." F. W. Achterberg, Junkers Corporation, Germany, will speak at the Diesel engine symposium where he will present a paper on "The Role of the Diesel in Aircraft."

A. E. Raymond, Douglas Aircraft Company, Inc., and R. J. Minshall, Boeing Airplane Company, will present papers on big airplanes.

Reprints of Wright Brothers Lecture

The Institute has 100 reprints of Dr. H. L. Dryden's Wright Brothers Lecture on "Turbulence and the Boundary Layer" and the accompanying discussion which appeared in the January, 1939 issue of the Journal. These are available at twenty-five cents each.

Change of Address

In order to expedite the work of the office, members reporting changes of address should also give their former address. Student members should give, in addition, the school they attend or did attend.

Branches

The February simultaneous lectures program sent out by the Institute to the Branches consisted of two papers, "A Terrain Clearance Indicator" by Lloyd Espenschied and Russell C. Newhouse, of the Bell Telephone Laboratories and "Instruments for Blind Landing" by J. Lyman and F. L. Mosely of the Sperry Gyroscope Company.

Carnegie Institute of Technology. On February 3rd the Branch held a smoker meeting at which the Boeing and Curtiss-Wright lectures, which formed the program for the January Simultaneous Lectures, were read by Harmon Crotsley and B. F. Grimm, and Charles Fegan, respectively. The presentation of the papers was followed by an interesting discussion of the points covered.

Boeing School of Aeronautics. Three meetings were held during the fall term. At the first, George M. Smith, Operations Engineer for Pan American Airways was the guest speaker. The films of European aeronautical laboratories were shown at the second meeting. At the third, B. C. Haynes, new Faculty Sponsor for this Branch, spoke on Meteorology and showed films demonstrating various phenomena. The total attendance at the three meetings was about one hundred and fifty.

University of Detroit. At a meeting on January 24th Prof. Peter Altman presented the Boeing and Curtiss-Wright Lectures. These lectures were well received as judged by the interesting discussions during and following the presentations.

Massachusetts Institute of Technology. On February 15th the Branch held a meeting completing the election of the following officers: Chairman, Welcome W. Bender; Vice-Chairman, Paul E. Sandorff; Secretary-Treasurer, Earl H. Swan; Honorary Chairman, Prof. Richard H. Smith. Prof. O. C. Koppen presented the Boeing and Curtiss-Wright lectures. About 180 students attended the meeting.

University of Minnesota. Fifty-five students were present at a meeting of this Student Branch on February 27th to hear Carl E. Swanson of the Electrical Engineering Department present the Espenschied-Newhouse paper. An interesting discussion followed the presentation.

Purdue University. At a meeting on December 19th Dr. H. L. Dryden's Wright Brothers Lecture on "Turbulence and the Boundary Layer" was presented by Prof. K. D. Wood. Dr. R. C. Binder gave a prepared discussion of some of the salient points.

Seattle. At a meeting on January 26th, coincident with the delivery of the first Boeing Model 314 to Pan American Airways, three papers were presented. The January Simultaneous Lecture on the Boeing 314 was presented by Alan Kelsey. Ralph Cram gave a paper on "Flight and Taxi Testing of the Boeing 314," and E. G. Emory spoke on "Interior Equipment and Furnishings of the Boeing 314." The meeting was well attended and the papers were followed by interesting discussions.

Tri-State College. About 60 students attended a meeting of this Student Branch on February 15th, at which the Boeing lecture, given by Author Mallory, and the Terrain Clearance Indicator lecture, given by Alex McCullach, were presented. Officers for the coming school year were nominated; the election will be held on March 15th.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

A Study of the Wing-Beats of Pigeons in Flight. G. Guidi. Observations on wing beats of pigeons, based on cinematograph films taken by the author, and characteristics of the wing and its lift in the various phases of the beat. Upward flight, horizontal flight with wings beating, fixed-wing flight, and hovering flight, as well as phases of the complete wing beat, are defined, and average times of each phase in ascending flight and horizontal flight with wings beating are discussed. Translation from *L'Aerotecnica* August–September, 1938. *Jour. Royal Aeronautical Soc.*, December, 1938, pages 1104–1115, 9 illus.

Results from the Deutsche Forschungsanstalt fuer Segelflug Smoke Tunnel. A. Lippisch. Smoke tunnel rendering it possible to visualize all phenomena occurring in two-dimensional flow. By blowing smoke into the uniform jet at point of greatest acceleration, it is possible to obtain clear smoke filaments over a field 3.3 ft. in height and 4.9 ft. in length. To make the air free from turbulence several wire nets with very close meshes are provided outside the entrance cone. As further increase in wind velocity gave rise to considerable depression within the tunnel, a second blower was provided at the entrance cone.

Long descripiton of design of tunnel includes also: means of introducing and cleaning the smoke, and for obtaining intermittent smoke delivery; characteristics of the tunnel; and camera with continuous film delivery up to a velocity of 100 ft./sec. and delivery by clockwork up to a frequency of 1000/sec. Problems investigated are explained with references to photographs which are not included in the preprint. *Royal Aeronautical Soc. Preprint* for meeting, December 15, 1938, 8 pages. Abstract, discussion, and photographs of smoke tunnel, flow over airfoils, different types of flaps, and Lippisch rotor wing. *Aeroplane*, December 28, 1938, pages 849–853, illus.

The Use of Model Data in Aeroplane Design. Miss F. B. Bradfield and D. L. Ellis. Tests which can be made in the designer's tunnel are considered especially in regard to the partial nature of model tests and their utility if limitations are appreciated and results correctly applied. This part of the discussion covers: drag measurement; drag due to leaks; high form drag; extra induced drag; interference; surface roughness; propellers; longitudinal stability tests; assessing merits of a particular cooling system from model tests; aerodynamic balancing of control surfaces; measurement of maximum lift; and measurement of local pressure distribution for stressing purposes.

Increasing the utility of model tests by use of special apparatus and by more extended or more elaborate experiments than possible in the stress of ad hoc work is discussed, especially the compressed-air tunnel, large tunnels high-speed tunnels, and free-flight tunnels. *Royal Aeronatuical Soc. Preprint* for meeting, January 5, 1939, 16 pages, 6 illus. Abstract and discussion referring among other things to the three fins and rudders on the Douglas DC-4 airplane. *Flight*, January 12, 1939, pages 43–46, 4 illus., 1 table.

Velocity Profiles and Flow of Fluids through a Contracted Pipe Line. F. V. A. Engle and A. J. Davies. Correction factor in the Bernoulli theorem, and effect of velocity profile on impact pressure. Experimental results obtained by Witte and Johansen on the influence of roughness and viscosity are shown. Ratio of calculated value of impact pressure at face of a constriction to the differential head across it is plotted against the velocity of approach factor for different velocity profiles. These curves are compared with experimental results of Engel and Witte, and with those of Johansen for impact pressure at low Reynolds Numbers, with a predominant viscosity influence. *Engineer*, December 30, 1938, pages 720–722, 9 illus., 22 equations.

Aircraft Design

The Case for Built-In Slots. Col. V. E. Clark. New Clark F-46A monoplane has a new plastic fuselage construction known as Duramold. Built-in slots over 25 percent of each wing markedly increase control beyond the stalling point. Angle of attack of the portion of the wing affected by the slot (the region of the upper surface in rear of, and slightly inboard of, the slot), at which maximum lift occurs, is increased by about 14°. Thus the slot delays the stalling of the tip of the wing and gives a favorable rolling moment due to roll at mean angles of attack of the wing as a whole much higher than that angle at which the portion of the wing inboard of the slot stalls. Explanation of the operation of the flaps. *Aviation*, January, 1939, page 35, 3 illus.

Contribution to the Calculation of Lift Distribution for Double-Section Wings in the Lowered Position. K. Jaeckel. Method is developed with the help of which one can calculate approximately the lift distribution over the lowered part of any double section wings of infinite width, and also is useful if both wings lie close together. Method is an amplification of the Birnbaum method for the double-section wing, and two Fourier series are calculated as a solution for the lift distribution in the lowered position. *Luftfahrtforschung*, December 10, 1938, pages 598–603, 7 illus., 1 table, 17 equations.

Elliptical Lift Distribution by Means of Warping and Profile Modification. Shih Cheng Zien. Investigation to determine in which trapezoidal wings elliptical lift distribution over the wing span is obtainable by warping or profile change. For a trapezoidal wing with a tapering ratio greater than $^1/_3$ an elliptical distribution with good lateral controllability in the stalled condition can be attained by warping or profile change, or both. For the trapezoidal wing with ratio less than $^1/_3$ an elliptical distribution without compromising lateral controllability can be obtained only by profile change or by profile change and warping. Lateral controllability is somewhat better with small tapered trapezoidal wings than with large tapered wings. *Luftfahrtforschung*, December 10, 1938, pages 604–613, 18 illus., 3 tables, 16 equations.

Present Status of the Development of Long-Distance Flying Boats. C. Dornier. Design and performance of flying boats of the United States, Germany, France, England, and Italy used in long-distance flights are surveyed and from the comparison the direction of future development is indicated. Design, type of construction, powerplant, wing loading, useful load, speed and range of European flying boats are described and compared with those of standard American long-distance flying boats. Design in regard to wings and hull and the powerplants used (conventional methods of installation, remote control, surface cooling and fuel tanks) are considered. Flying boats of over 40 tons under construction and contemplated are described. Tables give characteristics and performance for 14 European and 6 American long-distance flying boats, and for 3 French and 7 American boats under construction or projected. *V.D.I.*, January 17, 1939, pages 2–12, 33 illus., 3 tables.

Study of the Adaptation and Operation of the Airplane-Engine-Propeller Assembly by the System of Performance Curves. R. Silber. Problems of adaptation, operation and calculation of the performances of the airplane from the separate experimental characteristics of the elements which compose it, the airplane, engine and propeller. Many curves and equations are given. No. 123 Publications scientifique et technique du Ministére de l'Air. *La Technique Aéronautique*, 4th Quarter 1938, pages 259–281, 14 illus., 3 tables, many equations.

America "Sold" on Helicopters. R. Hafner. ". . . . whereas the Army is actively interested in rotary-wing aircraft, this type in its present state of development is not as yet sufficiently attractive to the U.S. Navy." Impressions gained during a visit to the United States are discussed with a brief account of a visit to Wright Field where "interest centered in the proposed low-torque high-performance helicopter." The First Rotating-Wing Meeting in Philadelphia is also described. *Flight*, January 5, 1939, pages 20–23, 9 illus.

The Flying Controls of the Aeroplane. G. T. R. Hill. Relation of control to stability; R.A.E. experiments on harmony of controls; pilots' opinions on control-force variation, stability with controls free, steadiness, stability of controlled motion, longitudinal trim changes, response to ailerons and rudder, and landing; quantitative measurement and specification of control; early attempts to measure control; "pleasant" control defined; position, velocity and acceleration controls; lag; theory and practice of the maintenance of trim; and recent developments including an improved method of balancing control surfaces, a quickly operable flap, aileron control replacement, two-control systems, and flying models. *Royal Aeronautical Society Preprint* for meeting, December 1, 1938, 17 pages. Summary of paper and discussion. *Flight*, December 15, 1938, pages 550e–550h, 6 illus.

Investigation of Stability. The coefficient of controllability. Consideration of what happens when the elevators are moved, what deflections are necessary in order to fly at all the angles, and the corresponding forces on the stick. *Les Ailes*, December 29, 1938, page 7, 2 illus., equations.

Methods of Solving Special Geometric Problems in Connection with Aircraft Design. H. E. Chaplin. Methods developed enable rapid solution of geometric problems presenting difficulty to draftsman and designer. Problems arise in cases where, although sufficient data is provided to enable ordinary three-view drawings of a particular part or assembly of parts to be made, angles and lengths have to be found which cannot be directly obtained from this three-view drawing. *Jour. Royal Aeronautical Soc.*, December, 1938, pages 1088–1103, 13 illus.

Technical Achievements of 1938 in Retrospect. Main events of the year (as previously reported in the magazine) are reviewed from the technical aspect and their significance in relation to the progress of aviation is discussed. *Aeroplane*, January 4, 1939, pages 17–20, 6 illus.

Stress Analysis and Structures

Experimental and Mathematical Investigation of a Monocoque Wing Model Loaded in Bending. E. Schapitz, H. Feller, and H. Koeller. Bending tests were made on a two-web monocoque wing model with cross load and pure moments to determine how the stress conditions differed from the results of the elementary bending theory. Longitudinal stresses were measured on the stiffeners with tensometers and the shearing stresses of the sheet panels computed therefrom. Measurements extended from low loads with non-buckled covering as well as to such in which, in the separate panels, the buckling limit had been exceeded. For purpose of comparison, the wing skin was computed as stiffened sheet according to the shearing panel scheme in which the statically indeterminate calculation was satisfactorily verified by measured results. D.V.L. report. *Luftfahrtforschung*, December 10, 1938, pages 563–576, 23 illus., 9 tables, 9 equations.

"Plastic Plane" to Speed Output. Clark F-46A or Duramold airplane (Ranger 12-cylinder inverted 450-hp. engine) produced by Clark Aircraft Corporation. "Duramold" is about $^6/_{32}$ in. thick and as its density is about $^1/_6$ of duralumin, it can be used in thicknesses six times those of orthodox aircraft skins made of that alloy. Since such thicknesses of Duramold do not tend to buckle under compression, it was possible to produce the fuselage of the plastic plane without internal bracing. Method for molding fuselages, developed by Col. V. E. Clark, is referred to. Airplane has received received C.A.A. approval and has been flown several hundred hours. Cruising speed is 200 m.p.h.

Celluloid Corporation is said to have been doing highly significant laboratory work on application of its sheet cellulose acetate Lumarith as a covering for fuselages and wings and its Lumarith tubes and shapes as strength members. *Business Week*, January 28, 1939, page 32, 1 illus.

Plywood Airplane Parts Built by Revolutionary New Method. Airplane wings, seaplane floats and other large aircraft assemblies are made by wrapping thin flexible plastic-bonded plywood sheets around formers, according to the new method being promoted by E. L. Vidal and Aircraft Research Corporation. After the sheets have been reinforced with stiffeners, the whole wing or other section is placed inside a rubber bag from which air is evacuated collapsing the bag around the plywood and forcing it around the formers. Wing and bag are placed in a steam curing oven and after curing, bag is removed and formers collapsed and withdrawn. Seaplane floats are being tested by the Navy. Short note. *Science News Letter*, February 11, 1939, page 84.

Prager Formulas Applied to Simple Bending. M. Précoul. Formulas are given for the wooden box spar of solid rectangular section, box spar of rectangular section having equal flanges, and rectangular box spar having unequal flanges. They are applied to simple bending but by the additions of the strains, they can be extended to combined bending. On the other hand they take into account only the resistance of the flanges without making the webs participate in the work of bending. Nomograms are given for spruce. To be continued. *L'Aérophile*, October, 1938, pages 227–228, 6 illus., 5 equations.

Note on the Effect of Rotation on the Frequencies of Lateral Vibrations of a Rod. J. Morris. Effect of imposed rotation on the frequencies of vibration. An empirical rule is indicated whereby effect of rotation may be assessed, and is shown for a uniform rod, to be a very close approximation, particularly with ascending overtones. In other cases, such as the tapered rod, the rule is shown to apply, but approximation is not so close. Formulas cover the uniform rod freely-hinged for the freely-supported and entirely free conditions, the uniform rod encastre at one end and free at the other, and

the case of a tapered rod encastre at the butt end. *Jour. Royal Aeronautical Soc.*, December, 1938, pages 1084–1087, 1 illus., many equations.

Plastic Progress. N. A. de Bruyne. Construction of an airplane front spar of reinforced synthetic resin, and method of making a typical spar joint by a system of interlocking dowels are described. Load on the joint at the root end exceeds 40 tons. Joint consists of dural plates sandwiched between synthetic material.

Gordon Aerolite, having linen instead of cotton reinforcement, is compared with Cord material, duralumin, spruce and steel in regard to physical characteristics and strength weight. Method of producing Gordon Aerolite is outlined. Impact figures and type of impact fracture observed are said to be satisfactory. Paper presented before Weybridge Branch, Royal Aeronautical Society. *Flight*, January 12, 1939, pages 38a–38c, 8 illus., 2 tables.

Tapered Beams. E. H. Atkins. Existing theoretical work generally available on tapered beams is reviewed and applied to girders with continuous webs. Tapered beams with uniform thin webs and concentrated booms of constant cross-sectional area are considered. It is shown that very appreciable additional stresses may occur which may be many times the average stresses required to balance the external loads. In some cases these stresses may be confined to the small area in the region of the apex. *Aircraft Engineering*, December, 1938, pages 371–374, 4 illus., 11 equations.

Torsional Stresses in Cylinders. J. Taylor. Principles of the convenient approximate method developed by A. Thom and J. Orr are explained with numerical examples given to show the practical stress man how to proceed. An improved approximation and a system of checking are included. *Aircraft Engineering*, December, 1938, pages 375–377, 10 illus., 6 equations.

Aircraft

Aeroplanes at the Paris Aero Show. Construction, engine, characteristics and, in case of military aircraft, armament of the following aircraft exhibited: Allar 04 sports two-seater; Aronca Chief two-seater tourer and trainer; Arsenal 30 C.1 single-seater fighter; Atalante GB-10 sports two-seater; Aubert Cigale two-seat tourer and trainer; Benes-Marz Superbibi Be555; Bloch 162 B.5 six-seater long-range four-engined bomber and 151C.1 single-seater fighter; Bristol Blenheim three-seater high-speed bomber; Caudron Cyclone single-seater fighter; Daspect sports single-seater; Dornier Do. 17 twin-engined bomber; Elytroplan experimental prototype; Fairey transport model; Farman NC 2234 four-seater long-range four-engined bomber; Fokker D.23 single-seater two-engine-in-tandem fighter; Gerard Club 45 sport and trainer; Guerchais No. 1 Type 25 two-seater sport; Hanriot H-182 ED2 two-seater general-purpose single-engined monoplane, Hanriot 232 two-seater twin-engined trainer, Hanriot 510 T.3 three-seater twin-engined reconnaissance; Hawker Hurricane single-seater fighter; Kellner-Bechereau E.5 No. 1 sports two-seater; Koolhoven F.K.58 single-seater fighter; Lignel 20s and Mistral single-seater racers; Liore et Olivier LeO.45 four-seater high-speed two-motored bomber; Loire-Nieuport L-N. 130 four-seater flying boat and C.A.O.200 single-seater fighter; Mignet H.M.210 two-seater trainer; Morane-Saulnier M.S.406 single-seater fighter; Morane-Sport sports two-seater; Phillips and Powis Miles Monarch two-seater tourer; Potez 662 four-engined 15-seater transport, Potez 63 three-seater bomber-reconnaissance fighter, Potez 160 two-seater experimental model of transatlantic flying boat; P.Z.L. LHOS twin-engined bomber, P.Z.L. Mewa observation, P.Z.L. Sum long-range reconnaissance and light bomber, P.Z.L. Wilk twin-engined fighter and dive bomber, P.Z.L. Wyzel twin-motored trainer; Romano R-82 two-seater aerobatic trainer; R.A.F. Supermarine Spitfire single-seater fighter; Hawker Hurricane; S.A.B.C.A. Caproni-Bergamaschi two-seater fast fighter bomber; Belgian Tipsy BC two-seater tourer; Vought V. 156 two-seater naval dive bomber; Bata Zlin XII two-seater tourer and trainer.

Other articles deal with engines and accessories exhibited. *Aeroplane*, November 30, 1938, pages 703–716, 31 illus.

The Airplanes at the Paris Show. R. Eisenlohr. Comments on the aircraft exhibited. *A.T.Z.*, January 10, 1939, pages 19–22, 6 illus.

An American Looks at the XVI Salon de l'Aviation. S. P. Johnston. Comments on the aircraft and engines exhibited. Both Benz and Junkers engines were fitted with carburetors whereas all the current production models seen going into aircraft in Germany were of the direct-injection types. *Aviation*, January, 1939, pages 26–27, 83, 6 illus.

The Military Aircraft of the 16th International Aero Show in Paris. G. W. Feuchter. Descriptions, and in some cases armament, characteristics, and performance of military aircraft exhibited at the Show and a few details of the engines. Among the illustrations are photographs of the Williamson 22 camera gun and of the machine-gun positions on the various aircraft. *Luftwehr*, December, 1938, pages 498–519, 67 illus.

Progress in Spain. New American airplanes of Russian origin sent to Red Spain by way of France seem to be taking part in the air fighting. Thirty-five Curtiss airplanes have been delivered to the Reds and type is now being manufactured under license in Spain. Machines "owing to their great speed, are difficult to handle." It is assumed that newspaper reports quoted refer to the Curtiss P-36 and a few details are given for this airplane which is said to do "something about 320 m.p.h." Bomb raids are discussed. *Aeroplane*, January 11, 1939, page 34.

Postscript to Paris. H. A. Taylor. Exhibits as viewed from a civilian angle. "If the larger commercial types were somewhat disappointing, the 'avions légers' were depressing." Lack of genuine commercial aircraft and of the tricycle idea except for the Fokker D.23 fighter; modern testing with flying models; American developments; Fokker D.23 fighter; P.Z.L. Wyzel twin-engined trainer; various light airplanes; Lorraine Algol radial engine with fuel injected into the induction system air-fed by a blower; "cinema-derivometre periscopique" tail drift sight; radio; and other equipment. *Flight*, December 8, 1938, pages 532–535, 6 illus.

The Civil Side at the Paris Show. Commercial and private-owner types of aircraft exhibited in full-scale or models are described briefly, among them; the Potez 662 12-passenger transport; Farman 2234 "Jules Verne" transport supercharged to fly at 20,000-25,000 ft. and having a cruising speed of 215 m.p.h. and gross weight of 55,000 lb.; CAMS 160 flying scale model and the 161; and S.E.200. *Flight*, December 1, 1938, pages 505–507, 8 illus.

Dive Bombers. "Actually interest in the naval dive bomber is now at a higher pitch than ever before." Blackburn Skua (Bristol Perseus engine) is now in large-scale production, and it is said that the first squadron will be supplied to the new carrier "Ark Royal." "Americans do not use their flaps to retard their speed in bombing dive, as will Skua pilots, though it is known that the Hamilton and Curtiss concerns have been developing reversible-pitch airscrews on behalf of the American Navy." References are made to American dive bombers and to the French Gourdou-Leseurre single-seater parasol monoplanes and Loire-Nieuport (S.N.C.A.O.) 40 monoplanes. *Flight*, January 5, 1939, page 12a.

An Aircraft Engineer in Paris. H. J. Pollard. Apart from various high-lift devices of certain airplanes on the Polish stand and the retractable tricycle landing gear on the Fokker D.23, the most striking feature of the Show was lack of new developments.

Design and construction are discussed as follows: Morane-Saulnier wing spar in which end fittings are integral with the steel flanges; slots and flaps on the Polish Mewa army cooperation machine and increased aerodynamic effectiveness of the tailplane through elimination of tip losses arising from normal three-dimensional air flow; twin rudders on the P.Z.L. "Sum" long-range reconnaissance and light bomber, Potez 662 four-engined bomber; Do.17 in which flush riveting is covered by paint of sufficient thickness to blend the heads into the surface; absence of dihedral; method used for making a stiff light door on the Do.17 with door frame of magnesium casting; A.Z. neat method of tank manufacture; clever automatic German riveting machine which drills, dimples and rivets at the rate of about 20 per minute; Bronzavia engine mount in which ring is spot welded but tubes have bolted socket joints. *Flight, Aircraft Engr. Sup.*, December 29, 1938, pages 75–78, 7 illus.

The Case for the Light Fighter. Caudron C.713 "Cyclone" (Renault 12-Rol 19-liter-capacity engine developing 450 hp. at 11,800 ft.) has a top speed of 295 m.p.h. at 13,100 ft. On test a pilot dived the prototype up to 430 m.p.h. and after pulling out executed three upward rolls, topping off with an Immelmann turn. Details of the Cyclone and advantages of this type of light fighter are discussed briefly. Italian Nardi F. N.305 light single-seater (260-hp. Hirth engine) was developed with a view to its functioning as an "assault" machine. It carries a fixed machine gun and 175 lb. of fragmentation bombs. *Flight*, January 5, 1939, page 12a.

FRANCE

Aircraft in Test. Brief references only to the following aircraft undergoing test: LeO-246 flying boat (four Hispano-Suiza engines of 2760-hp.). Bloch 174 attack and bombardment prototype (two Gnôme-Rhône 14-N20/21 engines developing 1030 hp. at 4000 meters). Dewoitine 514 arranged for launching parachutes (Hispano-Suiza 12-Y engine, speed 400 km./hr.). Morane 405–6 (Hispano-Suiza 12Y.51 1000-hp. engine, speed 510 km./hr.). Potez 63–11 (two Gnôme Rhône 14-Mars developing 670-hp. at 5000 meters) differing from production models in regard to a glass nose for observation. Another Potez 63 (two Pratt-Whitney Twin Wasp Junior engines developing 750 hp. at 3500 meters). Bréguet 460 Vultur (two new Gnôme Rhône 14-N. 20/21 engines). Dewoitine 520 single-seater fighter (Hispano-Suiza 12-Y 910-hp. cannon engine), and the 520 No. 2 (Hispano-Suiza 12Y.51 1000-hp. engine, speed 550 km./hr.). Amiot 351 bomber (two Gnôme Rhône 14 N. 20/21 engines, speed in excess of 500 km./hr.). Seversky P-35 pursuit exhibited at Villacoublay. *Les Ailes*, January 12, 1939, page 7.

Aircraft in Test. Brief references only to the following military aircraft in test: First issue—Bloch 135-B.4 prototype bomber (four Gnôme Rhône 14-Mars 660-hp. engines, weight 10,000 to 11,500 kg. when carrying four men, equipment and 900 to 1350 kg. bombs and armament, estimated speed 525 km./hr. at 5000 meters). Morane-Saulnier 405–7 (Hispano-Suiza 12Y engine) specially equipped for launching parachutes at high speeds. Latecoere 570 bomber (two Hispano-Suiza 14-AA engines). Caudron C-714 light single-seater fighter (Renault 450-hp. engine).

Second issue—Caudron C-714, Morane-Saulnier 405-7 (Hispano-Suiza 12Y-21 100-hp. engine cannon). Bloch 151 and 152 single-seater pursuits (one with Gnôme Rhône 14-N.21 1030-hp. engine and one with Pratt-Whitney Twin Wasp 910-hp. engine). Hanriot 232 bimotored trainer. Seversky 2-P.A. two-seater combat (Pratt-Whitney Twin Wasp engine) and P-35 single-seater pursuit presented to the French government at Villacoublay.

Third issue—Morane-Saulnier 405–7 (Hispano-Suiza 12Y-51 1000-hp. engine improving performance). Latecoere 523 Aldebaran military flying boat (six Hispano-Suiza engines). Centre 223.3 (four Hispano-Suiza 12-Y 860-hp. engines). *Les Ailes*, December 22 and 29, 1938, and January 5, 1939, pages 9, 9, and 8.

Two Interesting Salmson Prototypes: the Deville D4.S2 and the D.5 Experimental Airplanes. Salmson Deville D4.S2 shows that the two-engines-in-tandem formula has been studied in France since 1934, and the Salmson D.5 that France has developed a slow airplane, military qualities of which are said to be extremely interesting. D.5 experimental airplane is a two-seater high-wing monoplane having an additional lifting system. Handley-Page slot extends along the wing leading edge, ailerons have slots, and between ailerons and fuselage, about 2 meters on each side, Salmson flaps are located. Top speed 175 km./hr. when powered by one 110-hp. engine. Description of the D.5 and few details of the Deville D4.S2. *Les Ailes*, January 1, 1939, page 7, 4 illus.

Société Nationale de Constructions Aéronautiques du Centre. Few details and in some cases characteristics and performances for the following aircraft constructed by this company and by others of the French aircraft industry: S.N.C.A. du Centre—N.C.2234 four-engined high-altitude mail airplane; N.C.510 T.3 twin-engined two-seater observation; N.C.223 high-speed bomber with four engines arranged in tandem; Hanriot 220-I two-seater twin-engined fighter; Hanriot 232 bimotored advanced trainer; N.C.470 twin-engined advanced trainer seaplane; Hanriot 182 trainer.

S.N.C.A. du Midi—D.520 C.1 single-seater pursuit; D.342 trimotored commercial 24-passenger transport.

S.N.C.A. du Nord—Potez 63 three-seater light defense; Potez 662 12-passenger four-engined transport; Potez 160 flying model of the 161; Potez 141 four-engined military cruiser flying boat.

S.N.C.A. de l'Ouest—C.A.O. 200 single-seater fighter prototype; Loire 130 catapultable reconnaissance flying boat; C.A.O.30 seaplane trainer; Loire 21 catapultable pursuit seaplane.

S.N.C.A. du Sud-Est—LeO.45 high-speed bomber; LeOH.246 26-passenger four-engined flying boat; Romano R.82 two-seater trainer; LeO.H.47 mail and passenger transport flying boat; Sud-Est 200 six-engined long-range 20-passenger flying boat.

S.N.C.A. du Sud-Ouest—Marcel Bloch 151 single-seater day and night fighter; Marcel Bloch 162 B.5 day and night four-engined bomber; Marcel Bloch 135 B.4 high-speed four-engined bomber; Marcel Bloch 174 R.B.3, three-seater twin-engined reconnaissance and light bomber. *La Technique Aéronautique, Sup.* 4th Quarter, 1938, 8 pages, 15 illus.

French Aircraft. Construction, characteristics, performances, drawing and photograph of the following: Lioré et Olivier LeO H-246 transport flying boat for Mediterranean services (four Hispano-Suiza 12Xgrs and 12Xhrs engines, maximum speed 330 km./hr. at 2400 meters, range 1150 km.). LeO H-470 flying boat for South Atlantic service (four Hispano-Suiza 12Yirs and 12Yjrs engines arranged in tandem, maximum speed 355 km./hr. at 2400 meters, range 4000 km.). S.F.C.A. Taupin 5/2 training and towing airplane (Regnier 60-hp. engine, maximum speed 125 km./hr. at 1000 meters, range 500 km.). S.F.C.A. Lignel 10 fighter trainer (Renault 6Q03 engine developing 220-hp. at 2000 meters, maximum speed 325 km./hr., range 1500 km.). *La Technique Aéronautique*, 4th Quarter, 1938, pages 235–243, 8 illus.

A Tentative Non-Orthodox Single-Seater: N. R. Payen Pa-112 Flechair. N. R. Payen Pa-112-C.1 single-seater light pursuit having the sesquiplane-

tandem type of wings. Airplane is equipped with two Salmson 100-hp. engines operating two concentric oppositely-rotating propellers. Front wing is small and rear wing tapers from front to rear. Estimated maximum speed 460 km./hr. and range 800–850 km. Description of design, equipment, armament, characteristics, and performance. *L'Aérophile*, October, 1938, page 229, 2 illus., 1 table. The Payen Flechair Type Pa. 220–240 actually in construction will be equipped with a Ranger 315/330-hp. engine which will assure a speed of 450/480 km./hr. This a two-seater (transformable into a three-seater), will be tested in March. *Les Ailes*, January 12, 1939, page 7.

GERMANY

Aircraft of the German Military Aviation. Construction, and, in some cases, characteristics, armament and performance are given for 46 military aircraft of German fabrication as follows:

Single-seater fighters—Arado Ar68, Ar80, and Ar197; Messerschmitt Bfl109 (the only one of this group being constructed in series for the Luftwaffe); Focke-Wulf Fw159; Heinkel He51 and He112; and Henschel Hs123 fighter and light bomber.

Single-engined combat airplanes—Arado Ar81; Blohm and Voss Ha137B; Heinkel He118 and He170K; and Junkers Ju.87.

Multiplace single-engined general-purpose aircraft—Arado Ar95 catapultable light-bomber and reconnaissance seaplane; Dornier Do.22 torpedo and reconnaissance seaplane; three-seater Fieseler Fi156 Storch; Heinkel He45 reconnaissance and He60 reconnaissance seaplane; and Henschel Hs126 general-purpose.

Bimotored combat and reconnaissance—Focke-Wulf Fw57; Heinkel He111K; and Henschel Hs124.

Multi-engined night bombers—Dornier Do.17, Do.19 and Do.23; and Junkers Ju.86K and Ju89.

Multimotored flying boats—Dornier Do.18 long-distance reconnaissance and Do.24 reconnaissance and bomber for the Netherlands; Blohm and Voss Ha138 long-distance reconnaissance flying boat and Ha140 multiplace general-purpose seaplane; Heinkel He.59 and He.115 multipurpose seaplanes.

Training aircraft—Arado Ar96; Buecker Bue131 Jungmann and Bue133 Jungmeister; Focke-Wulf Fw44S Stieglitz, Fw.56 Stoesser and Fw.58 Weihe; Gotha Go.145 and Go.149; Heinkel He74; and Henschel Hs.121 and Hs.125.

Brief mention is made of the Messerschmidt Me110 (two Daimler-Benz D.B.601 1360-hp. engines, speed over 600 km. at 3000 meters), Focke Wulf single-seater fighter (double fuselage and pusher propeller), Junker Ju. 88 bomber (two Daimler-Benz D.B. 601 engines, speed 500 km./hr.), and the Heinkel He270K (Daimler Benz D.B.600 910-hp. engine) derived from the He.170K. *Rev. de l'Armée de l'Air*, November, 1938, pages 1256–1320, many illus.

Dornier Do.26 Transatlantic Flying Boat. Flying boat capable of transporting 80,000 letters over 9000 km. Maximum speed 335 km./hr. Cruising speed 310 km./hr. Short descriptions, characteristics, and views of the interior of the cockpit and other sections. *L'Aérophile*, October, 1938, page 223, 7 illus.

German Military Aviation. Development of German military aviation, and records made by some German aircraft. *Rev. de l'Armée de l'Air*, November, 1938, pages 1253–1256.

The Siebel Fh-104 and Si-202 Airplanes. Siebel Fh-104 five-seater twin-engined touring airplane of mixed construction. Two Hirth HM-508 170–240-hp. engines. Maximum speed 335 km./hr. Cruising speed 300 km./hr. Range 1200 km.

Siebel Si-202 two-seater powered by a 40- to 60-hp. engine. Maximum speed 155 km./hr. Cruising range 140 km./hr. Range 470 km. Brief descriptions, characteristics and performances of both airplanes. *L'Aérophile*, October, 1938, pages 221–222, 4 illus., 2 tables.

The Dornier Do.26 Transatlantic Flying Boat. A. Frachet. Dornier Do.26 is a catapultable flying boat of 20 tons which should be able to cross the North Atlantic in a single flight with 80,000 letters on board. Four Junkers Jumo 205 600-hp. Diesel engines. Cruising speed 310 km./hr. Maximum speed 335 km./hr. Maximum range 9000 km. Long description of construction, characteristics, and performances. *Les Ailes*, December 29, 1938, page 9, 3 illus.

Flying with the Luftwaffe. Dornier Do.17 bombers illustrated have two B.M.W. VI glycol-cooled engines. Newest models have inverted-vee twelve Daimler Benz engines said to give the airplane a maximum speed of 292 m.p.h. with range of 1490 miles. *Flight*, January 12, 1939, page 35, 5 illus.

The Handley-Page Wing Increases the Lift by 125 Percent. Information released by Handley Page regarding tests carried out at Bayerische Flugzeugwerke on a Messerschmidt Me-108B "Taifun" equipped with camber flaps and slots at the leading edge. Brief. *Les Ailes*, December 29, 1938, page 7, 2 illus.

Out of the Rut. Hamburg Ha-138 long-range reconnaissance flying boat (three Junkers Jumo 205C Diesel engines) has a very short central hull, and the tailplanes and fins and rudders are carried on two tail booms to provide unrestricted field of fire above and below the tail. Superimposed gun mountings in the stern, one turret firing over the tail unit and the other beneath it are illustrated. Maximum speed 171 m.p.h. Cruising speed 146 m.p.h. Range at cruising 1500 miles. Maximum overload range 3100 miles. Short note giving details, dimensions, weights, and performance. *Aeroplane*, December 28, 1938, page 854, 3 illus.

GREAT BRITAIN

The de Havilland Albatross Air Liner. Long description of design, construction, equipment, characteristics, and performance. *Engineering*, January 27, 1939, pages 89–91, 8 illus., 4 on suppl. plate VI.

Aeronautics in 1938. Progress in regard to streamlining, airflow and turbulence, all-metal construction, use of wood and plastics, speed and range, engines, gyroplanes, and landplanes versus flying boats. Typical British aircraft of the General Aircraft, Phillips and Powis, Handley Page, Short Brothers, Vickers Armstrong, Cunliffe-Owen, DeHavilland, and Percival Aircraft companies are described. *Engineer*, January 6, 1939, pages 8–12, 10 illus., 4 on suppl. plate.

Out of the Hat. Testing of the Handley Page Hampden bombers by Capt. J. H. Cordes, chief test pilot, is discussed, including undercarriage tests and ground running. *Flight*, December 29, 1938, pages 591–593, 9 illus.

The All-Metal de Havilland. D.H. 95, or Flamingo, 20-passenger transport (two Bristol Perseus XII C sleeve-valve 850-hp. engines). Few details of flight tests. *Flight*, January 5, 1939, pages 3, 16, 5 illus.. Brief note on first flights. *Aeroplane*, January 4, 1939, pages 4–5, 7, 8, 3 illus. Photographs only. *Flight* December 1, 1938, page 496c, 2 illus. *Aeroplane* December 28, 1938, page 834, 4 illus.

The R.A.F.'s Fastest Fighter. Vickers-Supermarine Spitfire eight-gun single-seater fighter, now being delivered in quantities to the Metropolitan Air Force, is said to be the "fastest standard fighting machine now on issue to any air force," top speed being more than 355 m.p.h. Rolls Royce Merlin II engine gives a maximum output of 1030 hp. at 16,250 ft. on 87-octane fuel. Specially developed Spitfire is being supplied to the R.A.F. for high-speed research. Cutaway drawing shows location of equipment. Long description of construction and equipment but no performance figures. *Flight*, December 1, 1938, pages 499–502, 5 illus.

The Short Sunderland. Sunderland, military conception of the Empire flying boat, retains most of the latter's structural features although design has been varied, particularly in the hull. Rear step has been completely redesigned. Gouge dragless type flaps, electrically operated, provide increased wing area and give normal flap effect. Four Bristol Pegasus XXII engines having maximum output of 875/915 hp. at 2600 r.p.m. at 6250 ft. Maximum speed 210 m.p.h. at 6250 ft. Overload range, still air, 2500 sea miles. Short description of construction, armament, dimensions, weights, and performance. *Flight*, December 8, 1938, pages 524–525, 1 illus.

Hauling down the Ensign. During their flying on the Paris and Empire routes of Imperial Airways, the Ensign class of air liners has shown the need for certain modifications of both aircraft and engine, and has been taken off the service for that purpose. *Aeroplane*, January 18, 1939, page 80.

The Retractable Auxiliary Wing. Advantages which the Fairey Aviation Corporation hope to get from their retractable auxiliary wing are given in an analysis of the estimated performance of the Fairey F.C.1 transport being built for British Airways, Ltd. when driven by four 1075-hp. Bristol Taurus sleeve-valve radial engines and loaded to 42,000 lb. Estimated landing speed with the retractable wing in action is 70 m.p.h. Because of reduced wing area estimated cruising and top speeds are 250 m.p.h. at 80 percent power and 275 m.p.h. respectively. Wing loading is 32.5 lb./sq.ft. *Aeroplane*, January 18, 1939, page 75, 3 illus.

Ultra-Modern. Fairey F.C.1 30-passenger transport (four Bristol Taurus 1000-hp. engines) having a pressure cabin, tricycle landing gear and low-drag flaps. For gross weight of 42,000 lb. estimated top speed is 270 m.p.h. and cruising speed 220 m.p.h. Wing loading is 32 lb./sq.ft. Flap is an auxiliary airfoil of approximately one third the chord of the main wing. In the intermediate position, it can be regarded as forming the lower wing of a sesquiplane, and, except for the usual allowance for biplane interference, it contributes its quota of lift without excessive drag. Preliminary details of airplane dealing mostly with the Fairey flap arrangement and its advantages. *Flight*, January 19, 1939, page 69, 2 illus.

HOLLAND

F.K.-50 Twin-Engined Transport. Koolhoven F.K.-50 high-wing monoplane transport accommodates ten passengers and crew of two. Two Pratt and Whitney Wasp Junior TB 406-hp. engines. Maximum speed 265 km./hr. Cruising speed 255 km./hr. at 2500 meters. Range 1000 km. at this height. Description, characteristics, performance. *L'Aérophile*, October, 1938, page 224, 4 illus., 1 table.

The Fokker D.23. Prototype Fokker D.23 single-seater fighter has two Walter Sagitta ISR 520-hp. engines arranged in tandem with pilot in between and supercharged to 13,450 ft., each driving a controllable fully-feathering V.D.M. three-blade electrically-operated propeller. Two synchronized 7.9-mm. Browning machine guns in the fuselage have a rate of fire of 1300 rounds per minute and two 13.2-mm. Browning shell-firing machine guns in the forward end of each tail boom can fire at the rate of up to 1000 rounds per minute. With Rolls-Royce Merlin or Daimler-Benz liquid-cooled engines, maximum speed is estimated at 385 m.p.h. Few details, characteristics and performance. *Aeroplane*, January 4, 1939, page 20.

POLAND

The P.Z.L. "Loup" Two-Seater Fighter. A. Frachet. "Loup" two-seater fighter monoplane is equipped with two "Foka" 12-cylinder inverted vee aircooled 450-hp. engines and wings have Handley-Page slots. Maximum speed 465 km./hr. at 4000 meters. Ceiling 10,000 meters. Range 1250 km. Long description of construction, armament, characteristics, performance. *Les Ailes*, January 5, 1939, page 9, 2 illus., 1 table.

U.S.A.

Aeronca 50 Hp. Flown Coast-to-Coast Non-Stop. Record distance flight demonstrating the light airplane's efficiency. Account of flight and description of equipment used. Distance of 2785 miles was covered by J. Jones in 30 hr. 47 min. *Aero Digest*, January, 1939, pages 81–82, 85, 9 illus.

Dart Moves West. Dart two-place cabin monoplane powered with the Ken Royce 90, Warner 90, or Lambert 90 engine. Maximum speed 135 m.p.h. Cruising range 550 miles. Brief note. *Western Flying*, December, 1938, page 23, 1 illus.

DC-5 Goes High Wing. Douglas DC-5 twin-engined high-wing monoplane having retractable tricycle landing gear and designed for short range operations with 16 passengers. Ability to get in and out of small fields, low wing loading and simplified maintenance are features of the design. Engine mounts, collector rings, control columns, rudder pedals and pilot seats are interchangeable with those of the DC-2 and DC-3. Maximum speed 224 m.p.h. at 6800 ft. with Cyclone G2 engines. Description, characteristics, and performance also with the Cyclone F62 and Hornet SIE2G engines. *Aviation*, January, 1939, pages 32–33, 4 illus., 1 table. *Aero Digest*, January, 1939, pages 56, 151, 7 illus.

Twin-Engine Lightplane. Edwards MBM-1 two-place low-wing light cabin monoplane powered by two Continental 50-hp. engines and having retractable landing gear. Maximum speed 122 m.p.h. Cruising speed 108 m.p.h. Cruising range 400 miles. *Aviation*, January, 1939, page 36, 2 illus.

The Wrong Angle of Attack. Wing loading of the Douglas DC-5, reported as only 22 lb./sq.ft. is compared with that of the DC-2,DC-3 and DC-4 on the basis of gross weight. "Thus the DC-5 has in reality a higher wing loading than one might have expected the Douglas people to have used for an airplane of such size." *Aeroplane*, January 11, 1939, pages 50–51, 1 illus.

U.S.S.R.

Table of Soviet Aircraft. Power plant, construction, characteristics, and speeds in take-off and landing are given in a table for 73 Soviet aircraft. Dates of prototypes are given, latest being 1937. Second table gives similar data for 32 engines, the largest engine developing 1250 hp. *L'Aérophile*, October, 1938, pages 231–232, 2 tables.

Aircraft for High Altitude Flight

Altitude of Navigation, 5000 Meters, Cabin Supercharging, to Start at 3000 Meters. Communication from engineers of the Junkers company discussing problems of commercial airplanes flying at high altitudes, and con-

cluding that it is possible to build a practical commercial airplane offering an interesting payload and disposable volume, which would be capable of flying above the highest summits. *Les Ailes*, December 22, 1938, page 8.

Engineering Aspects of Commercial High Altitude Flight. J. E. Younger. Paper and discussion. *Jour. Royal Aeronautical Soc.*, December, 1938, pages 1055–1083, 17 illus.

Pressure Cabin Experiments. New system of air control is used in the pressure cabin of the special Monospar Universal aircraft. Action is entirely automatic and apart from the fact that it is kept at normal pressure, the air is also kept at uniform temperature whether machine is flying or standing on the ground. Brief note only. *Flight*, December 8, 1938, page 539.

Aircraft Alighting Gear

A New Bendix Brake. "Newest and neatest Bendix aircraft-brake." Long detailed description of the Bendix fluid-operated two-leading-shoe brake with drawings and photographs. *Aeroplane*, January 11, 1939, pages 57–58, 4 illus.

Technical Notes. Tubes developed by the Société Archiméde for use in hydraulic controls have an internal diameter of 5 mm., length of 55 cm. and weigh only 55 grams. They have two metallic rings which offer a resistance to pressures of 130 to 140 kg. per sq.cm. without expansion or appreciable elongation. These tubes, flexible in all directions, can be twisted and bent and their covering is resistant to fire, and to all fuels and lubricants. Tubes do not lose their flexibility from 200° to −50°. They are used on French military airplanes, especially the Morane Saulnier 406. Brief note. *Les Ailes*, January 12, 1939, page 7.

New Type Landing Gear Wheels. Dowty wheel with intermediate pressure tires is supplied also with brakes and built-in oleo-pneumatic shock absorber. Four designs available cover aircraft between 6000 and 24,000 lb., and present designs include another for 68,000 lb. Impact loads are dissipated by a pin-jointed oleo-pneumatic shock absorber free from bending and racking loads. Wheel travel up to 18 in. can be provided and wheel may be cantilevered from a simple rigid strut. Few details. *Aero Digest*, January, 1939, page 147, 1 illus.

Power Brake Valve Developed. New Aircraft Accessories power brake valve includes a new type acumulator giving pressures ranging from 100 to 1000 lb./sq.in. Pilot always has a full feel of the brakes through the foot pedal which exerts a starting pressure of 2 lb. and a maximum pressure of 35 lb. on the valve lever arm. Few details. *Aero Digest*, January, 1939, page 147, 1 illus.

Aircraft Manufacture

Special Machines Designed for Flexibility in Aircraft Production. H. A. Berliner. Various types of hydraulic presses, drop hammers, power hammers or crowning rolls or wheeling machines, and hydraulic stretching presses, methods of cutting sheet-metal parts, and riveters used in aircraft production are described, including some in use in Germany and Great Britain as well as in the United States. *Aero Digest*, January, 1939, pages 65–66, 69, 10 illus.

Cutting and Forming Sheet Metal Parts. Cutting and forming machines and operations at Curtiss Aeroplane Division in Buffalo and at the Douglas Aircraft plant. *Aero Digest*, January, 1939, pages 60, 62, 69, 9 illus.

Important Lessons to Be Learned from American Practice. "The paper is encyclopedic in its scope and it is astonishing how much has been compressed into so short a compass." Long editorial praising T. P. Wright's paper before the Royal Aeronautical Society and his "breadth of mind." Features of particular interest to the British aircraft industry are pointed out.

The paper itself is reproduced in full with photographs. *Aircraft Engineering*, December, 1938, pages 369–370, and 386–411, 119 illus., 6 tables.

Machine-Made Planes. D. I. Carroll. Methods employed in the production of the Vultee V-11GB attack bomber. *American Machinist*, January 11, 1939, pages 1–4, 5 illus.

Modern Machinery for the Production of Aircraft and Engines. Newly developed machines and tools are described and their applications in the manufacture of aircraft and engines are reviewed. Addresses and other data concerning manufacturers of the machines are given in the directory section. Descriptions cover: presses, nibblers, routers and shapers, thread grinders, metal band saw, furnaces, welding equipment, grinders, lathes, finishing machines, radial drills, shears, boring and honing machine, drills, riveting machine, tapping machine, swaging machines, tools, and power control. *Aero Digest*, January, 1939, pages 100–144 (alternate pages), many illus.

Aircraft Accidents

An Open Question. Accident to the Lockheed 14, in which two experienced British Airways pilots were killed is said to be attributed to an error of airmanship. Report of inquest. Second brief note gives criticism of the Lockheed 14 from the French Service Technique "who say that it is not a safe and suitable aeroplane unless pilots who transfer to it from more elementary types have had adequate training on it." *Aeroplane*, January 11, 1939, page 32.

Air Transportation

The Azores as a Landplane Base. Capt. G. I. Thomson. Survey of the Azores for commercial flying. Short review of report. *Aeroplane*, November 30, 1938, page 726.

The North Atlantic in 1939. Imperial Airways plans for 1939 so far depend on the new Cabot class of Empire flying boats developed to carry heavier payloads and to be fueled in air. Real merits of the class as long-range carriers only come out when fueled in the air up to 53,000 lb. Three Handley-Page Harrows will be equipped to transfer 1000 gal. gasoline, two being stationed at Newfoundland and one in Ireland. Pan American Airways "are not so nearly ready as are Imperial Airways" for passenger, mail and freight service across the Atlantic. Lack of equipment is said to have cut the Pacific run by 40 percent. *Aeroplane*, January 11, 1939, page 53.

Trans-Canada Air Lines in 1938. S. J. Hungerford. Progress during the past year is reported by the president. *Aeroplane*, January 11, 1939, page 54.

Air Mail History. D. O. Lumley. Twenty years' development of British air mail services. *Flight*, December 8, 1938, pages 528a–528b, 3 illus.

Air Transport in 1938. Developments during the past year in regard to transpacific air transport, experiments on world routes, internal and continental lines, socialization, Europe, the Empire, U.S.A., equipment, airports, ground services, and control. *Aeroplane*, January 4, 1939, pages 24–26, 2 illus.

Atlantic Overture. H. A. Taylor. Serious full-scale air service operations between England and the United States are likely to be under way before the middle of the year. Plans involving a weekly service in each direction starting on or about June 1 are discussed. Take-off assistance versus refueling in the air, the Imperial-Pan American schedule, and what France and Germany are doing are taken up. *Flight*, January 12, 1939, pages 30–33, 10 illus.

Airships

New Blimp Delivered. Goodyear K-2, believed to be the largest nonrigid airship in the world, was recently delivered to the Navy. Length 246 ft. overall. Height 76-1/2 ft. Gross lift 25,000 lb. using 404,000 cu.ft of helium at 62 lbs./M. cu.ft. Two 550-hp. P. & W. engines. Few details. *Aero Digest*, January, 1939, page 28.

Propellers

Geared to the Skyways. P. H. Scheck. Methods used in the manufacture of Curtiss constant-speed propellers, including production of gears, high-quality forgings used, magnaflux testing, bearings to be stocked, and forging aluminum-alloy blades. *American Machinist*, December 14, 1938, pages 1081–1084, 6 illus.

A Simplified Method for the Calculation of Aircraft Propellers. A. Toussaint and Doussain. Method of calculation is based essentially on the principle that for the optimum propeller, the influence of the number of blades is manifested generally by a distribution of the circulation along the blade, pseudo-elliptic in $x^{\frac{3}{2}}$ where x, the relative radius, equals r/R. Method is developed and an example is given for the Hamilton Standard propeller. *La Technique Aéronautique*, 4th Quarter, 1938, pages 244–258, 7illus., 3 tables, 10 equations.

New Logarithmic Nomogram for the Determination of the Operating Characteristics of the Variable-Pitch Propeller in Cruising Speed Flight. G. A. G. Domenico. Possibilities of efficiency improvement introduced by the variable-pitch propeller in calculation of pitch/diameter and its use in normal cruising speed flights are examined. Author develops the theory for a new logarithmic nomogram giving the means for a rapid determination of these possibilities on the basis of characteristics of the propeller in cruising speed flight. Practical example is given for the case of determination of the optimum angle of pitch in cruising flights. Brief abstract from *L'Aerotechnica*, August–September, 1938. *Aircraft Engineering*, December, 1938, page 381.

High-Altitude Equipment

New Method of Administering Oxygen. Oxygen is supplied from vacuum jars filled with liquid oxygen and evaporation is controlled by means of copper wicks extending from the liquid oxygen. Exposed wick is so cold that it precipitates the expired carbon dioxide and water. Brief reference to method developed by Dr. P. Hartmann for administering oxygen, and details of the stratosphere test chamber of United Air Lines for testing oxygenation equipment under high-altitude conditions, and the performance of other equipment. *U.S. Air Services*, January, 1939, page 17.

Ice Elimination Equipment

Simplified De-Icing. Antice, spread with thumb and forefinger, adheres immediately and spreads out into a fine even film. The paste remains solid and firm and has withstood tests up to speeds in excess of 400 m.p.h. When a temperature of 34.5°F. is reached, paste starts to sweat over all its exposed surfaces. This chemical exudation continues down to 22°F. and even lower, and presence of the liquid on the surface of the paste prevents ice which forms from taking hold. Short description. *Flight*, January 12, 1939, page 48.

Parachutes

Three-Component Measurements on Parachute Canopies of Different Forms. H. Doetsche. Three-component measurements were made on five different parachute models of sheet metal in the 1.2-meter wind tunnel of the D.V.L. Influence of form of parachute canopies as well as influence of vertex opening and air discharge openings on air forces on the canopy were investigated. In conversion of moments to a point 1.33 diameter below the center point of the resistance surface corresponding to the c.g. position of a normal parachute, instability of the models for the position of equilibrium at vertical airflow was obtained and verified by special stability tests on the sheet-metal models. Same behavior could be observed on a silk parachute. D.V.L. report. *Luftfahrtforschung*, December 10, 1938, pages 577–582, 21 illus.

Miscellaneous

A French View of U.S. Sport Flying. Impressions of private flying in the United States which were received by M. Mignet who has been launching the American Mignet Aircraft Corporation in Chicago. Short note. *Aeroplane*, January 11, 1939, page 56.

Seaplanes on Land. G. B. Post. Safe landings on land can consistently be made by a seaplane under widely varying conditions without noticeable damage of any sort to equipment. Experiences are described. *Aviation*, January, 1939, pages 28–29, 84.

Forces Acting on the Catapult Car. Capt. H. C. Richardson. Theoretically it would be desirable to maintain the accelerating force at a constant value throughout the accelerated portion of the run, but practically this is difficult. Flywheel type of engine can be designed to give a close approximation. Forces and velocities acting in the different parts of the catapult; several methods of absorbing energy of the blow involved as car contacts the buffer at launching speed and sets the arresting cylinders to work; attitude of the airplane at launching; use of tumbling frames; events of launching viewed in the light of elapsed time; and launching the airplane with respect to the wind. *Aviation*, January 1939, pages 30–31, 1 illus.

The Catapult. Ransomes and Rapier "slider" catapult, developed from a design patented by the British Admiralty. Sliding member is made to travel along the main structure by a ram and a system of wire ropes, launching carriage proper moving forward on top of sliding structure. Launching is achieved through combustion (in a breech similar to that of a gun) of a charge of cordite, or by compressed air, both methods being in use in the British Navy. Recent batch of catapults, specially adapted for use with Grumman seaplanes, has been delivered to the Argentine. Description. *Flight*, December 29, 1938, pages 600a–600b, 5 illus.

Ancillaries at the Paris Aero Show. Review of aircraft equipment exhibited at the Show. *Aeroplane*, November 30, 1938, pages 721–722, 4 illus.

Flexible Airplane Fuel Tank Lengthens Period of Utility. Mareng fuel cell made by Glenn L. Martin Company consists of thin fabric impregnated with synthetic rubber. Oversizing relieves the fabric of all flying strains and stresses. Advantages and 700-hr. test are described. *Oil & Gas Jour.*, February 9, 1939, page 54, 2 illus.

In the Cause of Safety. Henderson safety fuel tank has successfully passed the drop, firing and flying tests at Farnborough and Martlesham. Walls are built up in three layers to a thickness of $^3/_{16}$ in. Inner wall of copper sheet with soldered joints, is coated outside with a thin film of "Hencorite" having many of the properties of rubber, this coating in turn being covered with an outer skin of the copper sheeting, soldered at all joints. Each layer of the tank is a complete leak-proof unit. Baffles attached to the inner wall are secured by special self-releasing device. Short description. *Flight*, December 29, 1938, page 605, 2 illus.

Acoustics

Nomogram Relating Sound Transmission through Partitions. A. E. Knowles. Contribution of various components to sound transmission for a composite partition, equivalent reduction factor of a composite partition, and difference in intensity level on two sides of a partition may be calculated by means of the nomogram. *Engineering*, January 27, 1939, page 110, 1 illus.

Apparatus for Acoustic and Audio-Measurements. H. A. Chinn and V. N. James. New automatic audiofrequency measuring assembly for reverberation and other acoustic measurements provides a means for automatic response versus frequency measurements of audio- and acoustic-equipment components and of complete audio systems. High-speed power-level recorder recently introduced in this country and new audio-frequency oscillator having exceptionally fine performance characteristics are used. *Acoustical Soc. Am., Jour.*, January, 1939, pages 239–245, 5 illus.

An Apparatus for Direct-Recording of the Pitch and Intensity of Sound. J. Obata and R. Kobayashi. Valve with quadratic characteristics was used in the wave-form adjuster to strengthen the fundamental tone, and, in order that input of the thyratron frequency meter shall be neither too large nor too small, a so-called symmetrical compressor was used instead of the simple volume controller of the former arrangement. Description of improved device. Authors are in the Physics Department, Aeronautical Research Institute, Tokyo Imperial University. *Acoustical Soc. Am., Jour.*, October, 1938, pages 147–149, 5 illus.

Aircraft Instruments and Navigation

Contribution to the True Measurement of Dynamic and Static Pressures in Flight. G. Kiel. Apparatus for measurement of dynamic pressures in flight invariably are located in the disturbed velocity field of the wing resulting in incorrect indications in the dynamic indicator and altimeter connected with the static pressure pipe of the impact apparatus. In a field between upper and lower biplane wings undisturbed flow velocity is present, but on the monoplane, in the area considered for impact apparatus, there seems no place in which undisturbed dynamic pressure occurs independently of flight condition.

Two methods are discussed which, even in the case of the monoplane, permit correct measurement of undisturbed flight dynamic pressure and true static pressure. Second method, developed by the author, is said to be readily applicable and to present a completely satisfactory solution in every instance. *Luftfahrtforschung*, December 10, 1938, pages 583–597, 23 illus., 12 equations.

Limits of Usefulness of Blind Flying Instruments. H. Nautsch. Deficiencies and limitations in the use of German blind flying instruments are discussed in order to make clear to the pilot what he may expect from the instruments and what possibilities of error he must consider. At the same time it is intended to demonstrate to the engineer the present defects of his instruments. Emphasis is placed on the physical limits of instrument performance rather than on the technical possibility of errors and life of the various instruments since these vary greatly with different designs. Turn indicator, magnetic compass, gyroscope, gyroscopic horizon, variometer, altimeter, and speed indicator are considered. *Luftwissen*, December, 1938, pages 437–441, 4 illus.

Navigation—Fourth Rate or First Class? F. Chichester. Practical examples of right and wrong methods of navigation. Navigational details of a British Airways survey flight from Stockholm to Heston are shown on a chart laid out on Mercator's projection. Modern airline practice of combining three methods of air navigation is described. *Flight*, January 19, 1939, pages 54–56, 2 illus.

New Take-Off Measuring Apparatus. R. Von Chlingensperg. Messerschmidt apparatus for measuring the take-off and landing run of airplanes consists of three parts: the auxiliary apparatus for angle measurement, principal observation apparatus for time-angle measurement, and apparatus for evaluation of diagrams. Long description and example of its use. *Luftwissen*, November, 1938, pages 417–420, 11 illus., 1 table.

A Pilot Has Invented a Slide Rule for Navigation. Slide rule designed by M. J. Hennequin comprises the following scales: upper altitude scale (1000 to 10,000 and 100 to 1000); lower left three superposed graduations giving time values from two to 25 hours; on the right two graduations furnishing "distance" from 18 to 1650 km. or 16,500 km., and fuel consumption from 18 liters to 1650 or 16,500 liters; on upper level of the rule graduations from 0 to 23 cm. permits direct readings on the projections from 1/1,000,000th up to 220 km.; on the lower edge another scale for projections up to 1/1,500,000th up to 330 km. Movable part carries graduations of 1 to 9 reported twice and presenting values in meters per second; intermediate scale being carried out to angular values of 0 to 90°; lower scale carrying values of 111, 111 to 500 representing km./hr. or consumption in liters per hour. *Les Ailes*, January 12, 1939, page 7, 1 illus.

Study on the Subject of the Use of the Radio Compass on Aircraft. Lt. H. Muller. Practical solution, by means of a graphic method, for the problem of connecting the airplane with reference to a fixed station, knowing the bearing, measured on the radio compass, of the station with respect to the airplane. A simple means is found for drawing the radio courses corresponding to a given transmitter. Several networks of radio courses are studied comparatively and it is shown that under some conditions they can be superposed; that is, that it is possible to construct one network of radio courses capable of being applied to any transmitter whatever. The radio course is represented on the sphere and the procedures for drawing on a chart at 1/1,000,000th is explained, for drawing on the Mercator triangulation, and for drawing on stereographic projection are explained. Network of radio courses on a Favé-Brill triangulation is shown. *Rev. de l'Armée de l'Air*, November, 1938, pages 1223–1229, 4 illus.

Supply Division Marketing New Compass, Work Lamp. Carwil type 55-P magnetic compass for light aircraft. Few details of compass and also of the Dazor floating lamp which is useful for airline maintenance as well as in engineering departments of aircraft factories. *Aero Digest*, January, 1939, page 147, 2 illus.

Testing Apparatus

Mechanical or Electrical Apparatus for Measuring Rapidly Variable Processes. J. Geiger. Dynamic properties of measuring apparatus, in particular its natural frequency, should be given greatest attention. Frequencies used should be considered and it should be ascertained whether the apparatus is well suited in this regard. Other properties such as true reproduction of measuring qualities, exclusion of error possibility, simplicity of operation, as well as immediate possibilities of evaluation should not be disregarded. Long discussion. *A.T.Z.*, January 10, 1939, pages 1–5, 8 illus., equations.

The Physical Society's Exhibition. First issue—Everett Edgcumbe self-protected earth leakage indicators and recorders, and universal testing set; Ferranti low-range light tester; Van Der Graaf 250-kv. electrostatic generator; Westinghouse Noreg constant-potential system and Westat floating battery system. Guênault and Lloyd recording microphotometer; and Marconi wave analyzer.

Second issue—Salford motor-protection thermostat, Gecalloy radio coil, and high-frequency terminal. General Electric apparatus for measurement of magnetic field strengths and new multi-range photoelectric potentiometer. Leland Ballantine sensitive electronic voltmeter. Illuminated dial ammeter. New Hilger Dekkor inspection enlarger, new medium quartz spectrograph, and large Littrow instrument fitted with optical trains of glass and quartz. British Physical variable condenser gaging bridge, and recording viscosimeter. Automatic Coil Winder Company low-resistance ohmmeter and Avo test bridge. Igranic contactor "across the line" motor starter, and long time delay relay. Descriptions. *Engineer*, January 20 and 27, 1939, pages 90–92 and 116–118, 16 illus.

Kent specific-gravity recorder; Philips X-ray tube for crystal analysis; Sullivan micrometer condenser; Mercer dial-gage type extensometer; Marconi portable battery-operated pH meter; Hughes instruments for aircraft and ships including a dead reckoning computer for aircraft supplied to the British Air Ministry and electron compass; Short and Mason combined Fulscope humidity and temperature recording controller, "Valve Precisor," and binec thermometer tube; Hilger-Barfit automatic spectrograph; Bellingham and Stanley monochromatic illuminator. Short descriptions. *Engineering*, January 27, 1939, pages 102–305, 98, 9 illus.

Recent Advances in the Use of Acoustic Instruments for Routine Production Testing. B. Foulds. Development of a continuously-variable wide-band filter system similar to the heterodyne type frequency analyzer seemed necessary for the design of apparatus for production testing in which the intensity of sound is used as the measure. Design of a filter system having a large number of steps was attempted and a novel mechanical design was worked out which is described. Applications to the testing of electric fan motors, ball bearings, fan motors for automotive use, hardness of grinding wheels and other products are described. General types of acoustic pick-ups or microphones applicable under different circumstances are described including exposed microphone, shielded microphone, muffler-type pickup, and sound-proof box. *Acoustical Soc. Am., Jour.*, October, 1938, pages 128–134, 10 illus.

Metals

Metallurgical Developments in 1938. Recent developments in both practical and theoretical nonferrous metallurgy, including: casting and fabrication; surfacing; alloy development and improvement; alloy constitution and metal structure; age hardening; diffusion in solid metals; metal stressing and deformation; crystallization from the melt; and corrosion.

A summary of some metal constitutional systems investigated in 1938 and compiled by B. W. Gonser and A. U. Seybolt, is also given. *Metal Industry*, January 13, 1939, pages 29–34, 1 table.

Alnico—Its Properties and Possibilities. J. Q. Adams. Field of usefulness, physical and magnetic characteristics, hysteresis loops, comparison of permanent magnetic materials, and applications. *General Electric Rev.*, December, 1938, pages 518–522, 10 illus., 1 table.

The Automobile Research Committee. Drawing and cold working properties of steel investigated by the Committee. Research equipment and processes employed at Sheffield University are described and results obtained are discussed, covering: various stresses and strains during drawing; quench-aging of steel and strain aging of automobile strip; strain-aging effects; and steels tested in a similar manner with both tensile and Vickers diamond hardness tests. *Automobile Engineer*, December, 1938, pages 461–465, 11 illus.

New Anti-Corrosion Process. Royal process, already being used on government work, employs electrolytic means involving use of a special bath and "entirely novel and complex electrodes." A mixture of metals—in effect and alloy—is deposited on the base metal. By use of accelerators thought actually to increase speed of impinging particles, such deposition is found to penetrate the metal pores so that they are completely closed by the resistant alloy. Short note. *Flight*, January 5, 1939, page 23.

Notes on Welding Practice. J. G. Waterworth and A. R. Mowbray. Nature of oxidation and carburization and their cure in the welding of light metal alloys. Discussion covers: excess of oxygen or carbon; sectioned and etched specimens; dangerous second runs; application of a deoxidizer; use of a gas flame playing on the part and enclosing the joint; internal scale in a tube; and welding of engine cylinders without incurring the expense of final reboring and fitting of oversize piston. Drawing shows how antioxidation paste can be applied when a component has to be welded while another is within it. *Aircraft Engineering*, December, 1938, pages 382–385, 9 illus.

Relation between Mechanical Properties and Service Results. L. W. Schuster. Tensile tests, yield point, ductility, bend test and fatigue test are considered in regard to their use in determining suitability of the material for service. To be continued. British Institute of Metals paper. *Heat Treating and Forging*, December, 1938, pages 616–619, 4 illus.

Valve Spring Materials. H. E. Blank, Jr. Metals used in automobile-engine valve springs, spring fatigue value of heat treatment, corrosion, and a typical procedure for fabricating springs. *Automotive Industries*, January 21, 1939, pages 72–76, 5 illus.

The Oxide-Coated Filament. C. H. Prescott and J. Morrison. Relation between thermionic emission and content of free alkaline-earth metal. Contribution from Bell Telephone Laboratories. *Am. Chemical Soc., Jour.*, December, 1938, pages 3047-3053, 6 illus., 5 tables.

Progress in Powder Metallurgy. W. D. Jones. Survey of past work and future possibilities. *Metal Industry*, January 13, 1939, pages 51–55.

The Production and Industrial Uses of Titanium. G. F. Comstock. Manufacture of pure titanium, titanium in nonferrous alloys, titanium alloy steels, and applications as an alloying element in steel. Correlated abstract. Concluded. *Metals & Alloys*, November, 1938, pages 314–318, 10 illus., 2 tables.

Corrosion and Protective Coatings

The Protection of Metal Surfaces. T. P. Hoar. Protection by alloying additions to metal, and protective nonmetallic and metallic coatings. Selective oxidation; oxide films on aluminum; nonmetallic coatings on magnesium; anodic coatings on tin; hot-dipped coatings; electrodeposited coatings and other metallic coatings; protection against specific circumstances, testing methods for metallic coatings; and modification of the corrosive medium. *Metal Industry*, January 13, 1939, pages 83–90, 6 illus.

Iron and Steel

Internal Stresses in Castings. C. W. Briggs. Stresses in cast iron; internal stresses in cast steel; contraction stresses; stress centralization; and magnitude of stresses at hot tearing temperatures and at room temperature. *Welding Jour., Welding Res. Sup.*, January, 1939, pages 22–27, 8 illus.

Shearing, Blanking, Drawing, Spinning, Forming, and Riveting of Stainless Steel. Recommendations regarding these processes as applied to stainless steel. From Republic Steel Corporation booklet entitled "The Fabrication of Republic Enduro Stainless Steel." *Iron Age*, February 2, 1939, pages 37–41, 6 illus.

Non-Ferrous Alloys

Age Hardening of Duralumin. M. Cohen. Basic aging mechanism involves a preprecipitation stage as well as actual precipitation. It is believed that the preprecipitation stage is a process of nucleus formation in preparation for the precipitation of $CuAl_2$. When precipitation occurs, it does not take place uniformly. Localized precipitation sets in first along the grain boundaries, and this is ultimately followed by general precipitation within the grains. Tests and results described. A.I.M.E. paper. *Metal Industry*, December 30, 1938, pages 629–633, 6 illus.

Composition and Properties of Cupaloy in the "Time Capsule." P. H. Brace. Heat treatment for hardening and properties of Cupaloy. *Metals & Alloys*, November, 1938, pages 311–313, 6 illus., 4 tables.

Extraction, Properties and Fields of Application of Electrolytically Purified Aluminum. H. Roehrig. According to the three-layer method developed on the fundamental principles originated by A. G. Betts, aluminum of very high purity can be produced. Characteristics of this metal of more than 99.99 percent aluminum opens fields of application so far denied to other metals. Electrolytical refining of aluminum by the Betts and Hoopes methods is described and the properties of purified aluminum and of the alloys manufactured from them, as well as applications, are discussed in detail. *V.D.I.*, January 7, 1939, pages 33–39, 7 illus., 4 tables.

Light Alloys for Aircraft. H. Sutton. Failures under steady stress and corrosion, spot welding of light alloys, and light-alloy rivets used in aircraft construction. Discussion following the paper and author's reply are included. *Metal Industry*, December 30, 1938, pages 637–640, 6 illus.

Riveting

Explosive Riveting. Explosive charge, according to rivet size of 2.6 to 6 mm. diameter, weighs 4 to 25 mg. and is such that by heating after 2 to 3 seconds it explodes at approximately 130° temperature. Rivet warmer with conical point of silver or aluminum is placed on the rivet head from the outside. Resistance to shear of a riveted joint made with explosive rivets is approximately 15 percent less than that of the conventional riveted joint, since the material loses strength as a result of heating. Shearing strength of the rivet corresponds to that of the conventional rivet. Short abstract of article by P. Nemitz in Heinkel publication, 1938, No. 4, page 125, and of another by O. Butter, "Werkstattstechnik," 1938, No. 21, page 465. *V.D.I.* December 24, 1938, pages 1492–1493, 2 illus.

Welding

Effect of Aluminum on the Welding of Steel—Review of Literature to July 1, 1937. W. Spraragen and G. E. Claussen. Welding carbon-aluminum steels (filler rods, aluminum killed steel, high iron-aluminum alloys, forge welding, resistance welding, flame cutting); welding Nitralloy; welding Cr-Al heat-resisting steels; and suggested research problems. *Welding Jour., Welding Res. Sup.*, January, 1939, pages 8–11.

Recent Advances in Resistance Welding. L. B. Hunt. Spot, seam, butt and flash welding of aluminum alloys, magnesium alloys, and copper and nickel and their alloys.

Second article by H. W. G. Hignett, entitled "Fusion-Welding Non-Ferrous Metals," stresses the need for stimulating fundamental research, and a third, "Progress in Soldering and Brazing" by C. L. Ashby describes new joining methods and materials. *Metal Industry*, January 13, 1939, pages 69–73, 74–76, and 77–81, 13 illus., 1 table.

Some Present-Day Problems of Strength in Structural Welding. G. Bierett. Sensitivity of steels to welding; tests for sensitivity to welding; shrinkage stresses and other sources of danger; shrinkage stresses in welded girders; and increasing the quality of welded structures. Translated from German. *Welding Jour., Welding Res. Sup.*, January, 1939, pages 17–21, 7 illus.

Plastics

A Jointing Problem Tackled. New Bakelite F.5522 is based upon the fact that while the plastic material is being pressed it is capable of adhering to wood. Bakelite core is faced with wood and as the synthetic resin bonding material does not penetrate to the outer surface of the wood, the latter retains its ability to be joined to a wooden member by any well-tried gluing process. F.5522 has a high bearing strength (25,000 lb./sq.in. permissible loading). Brief note. *Flight*, January 12, 1939, page 36, 1 illus.

Plastometry of Synthetic Resins. R. Houwink and P. N. Heinze. When testing the value of resins, especially the hardening of synthetic resins, the two properties to be given most consideration are hardness (weakening point) and the hardening velocity. New apparatus to measure these properties, particularly the Schopper-Houwink plastometer, is described. Experimental results are discussed with their technical and scientific applications. *Industrial and Engineering Chemistry, Anal. Ed.*, December, 1938, pages 680–683, 10 illus., 2 equations.

Wood-Faced Laminated Material. New material developed for the specific purpose of strengthening wood members in aircraft construction has been introduced by Bakelite, Ltd. and is intended for use where ends of members are subjected to heavy shearing or bearing forces. This material is a wood-faced laminated sheet so constructed that adhesion between wood face and core of Bakelite material is greater than that of the shear strength of the wood, while wood surface itself is unaffected by any penetration of the synthetic resin bonding material. Example of use is that of joining wing spars to the fuselage. When inserts are incorporated strength of joint is greatly improved. Short note. *Engineer*, December 30, 1938, page 742, 1 illus.

Progress in the Field of Synthetic-Resin Gluing Processes. W. Kuech. Among the large number of binding agents with synthetic-resin bases used in aircraft construction, the methods of most importance are the Tegofilm in the production of plywood and veneers by heated gluing, and the gum copal gluing for additional working of materials into structural parts by the cold glue method. Whereas development of the Tegofilm may be regarded as practically completed, various improvements have been recently suggested in the working of gum copal glues and are discussed here.

New and improved method for the use of binding agents of urea-formaldehyde resins is described. By development of gum copal cold-glued powder, the limited storing properties of the liquid gum copal glue are eliminated. Gum copal glue powder, the gum copal gluing method used at the Buecker aircraft plant, Klemm gluing method, strength of glued joints at high temperatures and high humidity, and gum copal films are discussed. *Luftwissen*, December, 1938, pages 427–431, 9 illus., 3 tables.

Protein Plastics from Soybean Products. G. H. Brother and L. L. McKinney. Seventy commercially available plasticizers were tried with formaldehyde-hardened soybean protein. Polyfunctional alcohols gave positive results as plasticizing agents and of these ethyl glycol was best. Primary monohydric alcohols, esters, ketones, and oils gave most definitely negative results. Oleastearates, in mixture with ethylene glycol, reduced water absorption more than any other agent tried. Tests and results. *Industrial and Engineering Chemistry, Ind. Ed.*, January, 1939, pages 84–87, 2 illus., 3 tables.

Rubber

The Mechanical Characteristics of Rubber. F. L. Haushalter. Behavior as an engineering material in tension, compression, shear and torsion. *India Rubber World*, January 1, 1939, pages 39–42, 50, 8 illus., 2 tables.

Rubber as a Load-Carrying Material. F. L. Haushalter. Rubber as a load-carrying and structural material, and why it is best to limit stresses and strains in the rubber structure to definite values when applied in this manner. Latex, raw rubber, and the structure of rubber, theoretical and otherwise are discussed. Limitations for the proper use of rubber are determined by long-time creep or slip in the structure which, in turn, is related directly to the magnitude of stress and distortion in the material. Vucanized rubber is practically incompressible, and, when properly confined, can be loaded safely to terrific pressures just like any fluid. *S.A.E. Jour.* (*Trans*), January, 1939, pages 15–22, 18 illus.

Miscellaneous Materials

A New De-Greaser. Brown Gunk DP hydro degreasing solution does not leave an oily film, will not harm paint or fabric, is noncorrosive and perfectly safe to handle and does not vaporize. It can be applied cold and needs no equipment or tedious preparation. *Aeroplane*, January 18, 1939, page 87.

Results of Tests of the Use of Hemp Cable for Towing of Aircraft. Blechschmidt and Hohenner. Test results discussed. *Luftwissen*, December, 1938; pages 443–444, 3 illus.

This Year We Honor. New products that became commercially available in 1938, covering materials and instruments for their testing. *Industrial and Engineering Chemistry, Ind. Ed.*, January, 1939, pages 12–17, 3 illus.

Material Research Discussed at the Lilienthal-Gesellschaft for Aeronautical Research. Research on duralumin, deep-drawing sheets, manufacture of alloys, heat hardening, magnesium and aluminum-magnesium alloys, crankshaft steels, valve springs from German steel, valve materials, exhaust-gas silencers, pistons, rings and cylinders, light metal welding, synthetic materials, and non-destructive testing. Reprint of special report issued July, 1938. *A.T.Z.*, December 25, 1938, pages 625–628.

Meteorology

The Design and Performance of Radio Equipment for Radio-Meteorographs. C. B. Pear, Jr. Method of approach to the problem, choice of frequency, receivers, signal paths, transmitters and batteries, and frequency stability. *Am. Meteorological Soc., Bul.*, September, 1938, pages 299–309, 9 illus.

Gustiness in Stormy Weather. H. Arakawa. Comparison of the Dines and Robinson anemometers in the Muroto typhoon. *Am. Meteorological Soc., Bul.*, September, 1938, pages 280–281, 1 illus., 1 table.

Hyperbolic Dividers for Geostrophic Wind Computations A. F. Spilhaus. Dividers designed to estimate, from spacing of the isobars, the wind travel in a given time or the wind velocity. Computation is performed automatically with great facility and one instrument can be used on a wide variety of map scales and for any latitude. *Am. Meteorological Soc., Bul.*, October, 1938, pages 351–353, 2 illus.

Isentropic Airplane Flights—A Suggestion. A. F. Spilhaus. To supplement inexpensively and easily the information of the regular aerological network and to provide data which will be of great value in demonstrating fundamental principles of the mixing processes in the isentropic surface, it is suggested that an airplane equipped with an ordinary aerometeorograph be flown along a preselected isentrope. Procedure is described. *Am. Meteorological Soc., Bul.*, September, 1938, pages 279–280.

Ice Accretion on Aircraft (Notes for Pilots). G. C. Simpson. Physics of ice accretion is discussed giving an explanation of the different forms in which ice accretion appears on aircraft. The meteorology of ice accretion which is mainly concerned with formation of clouds, formation of precipitation, and the temperature is considered. *Am. Meteorological Soc., Bul.*, October, 1938, pages 326–329.

Balloon Transmitters. I. M. Hunter. Automatic transmitter designed for fitting in a balloon used in carrying out investigations on the electrical properties of the upper atmosphere. *Wireless World*, December 29, 1938, pages 585–587, 3 illus.

The Duration and Intensity of Twilight. H. H. Kimball. Duration of astronomical and civil twilight, and the intensity of twilight. *Monthly Weather Rev.*, September, 1938, pages 279–286, 1 illus., 6 tables.

The Hailstorm of April, 1938, at Washington, D. C. "Unusual Fall of Large Hailstones at Washington, D. C.," G. Slocum. "The Formation of Irregularly Shaped Hailstones," D. L. Arenberg. "Structure of Hailstones." *Monthly Weather Rev.*, September, 1938, pages 274–277, 2 illus., 6 equations.

Hurricane of September 16 to 20, 1938. Tropical storms in New England; the hurricane of 1938 at sea; hurricane in coastal areas and in New England; destructive effects of the hurricane; inundation damage and loss of life; and warnings. *Monthly Weather Rev.*, September, 1938, pages 286–288.

On the Use of Vertical Cross Sections in Studying Isentropic Flow. C. H. Pierce. Cross section constructed with isotherms of potential temperature and of condensation temperatures has the following advantages over the one drawn which uses temperature and specific humidity: it has thermodynamic significance; it roughly shows convective instability of air; slope of many isentropic surfaces is shown and, because fronts follow isentropic surfaces, position and slope of fronts which cut the cross section plane can be identified. *Monthly Weather Rev.*, September, 1938, pages 263–267, 7 illus.

A Practical Method for Computing Winds Aloft from Pressure and Temperature Fields. E. M. Vernon and E. V. Ashburn. Method for determining what upper winds should prevail at a given moment, past or present, by both qualitative and quantitative consideration of the distribution of pressure and temperature. It is supposed that the wind at any level in the upper air is directly related to the distribution of pressure at that level by the gradient wind equation. The well-known equation expressing pressure-height-temperature relation is accepted as the fundamental concept necessary for determination of pressures in the free air and therefore of pressure gradients at any upper level. Wind scales for measuring isobaric and thermal components, corrections for temperature and pressure, and use of the wind scales are discussed with examples. *Monthly Weather Rev.*, September, 1938, pages 267–274, 3 illus., 17 equations.

Weather Phenomena of the Colorado Rockies. R. L. Ives. From field observations in the mountain regions of Colorado, it was determined that the major portion of the state's moisture is brought in by winter cyclones. Summer storms of three types tend to redistribute the moisture derived from melting snow. Numerous barometric, electrical and optical phenomena of great interest but minor climatic importance are described briefly. Hypotheses explaining various major and minor phenomena are presented, and possible applications of this and further studies in aviation are suggested. *Journal Franklin Institute*, December, 1938, pages 691–755, 20 illus.

Local Forecasting of Heavy Winter Precipitation at Blue Hill. H. G. Dorsey, Jr. First issue—Study of seven great snowstorms of the winter type, 1933–38, and a study of two spring-type snowstorms. Second issue—Use of Mt. Washington data in short-term forecasting for Boston. *Am. Meteorological Soc., Bul.*, September and October, 1938, pages 281–297 and 335–339, 15 illus.

The Ohio River Flood of 1937. W. C. Devereaux. Conditions leading to the flood and flood forecasting. *Am. Meteorological Soc. Bul.*, October, 1938, pages 330–333.

On the Frequency Distribution of Sleet-Drop Sizes. H. Landsberg and H. Neuberger. Results of measurement of sleet drops during a heavy sleet storm at State College, Pa. *Am. Meteorological Soc., Bul.*, October, 1938, pages 354–355, 1 illus., 2 tables.

Studies of Tropospheric Changes and Radio Reception. R. C. Colwell and A. W. Friend. Lower region of the atmosphere (troposphere) influences the propagation of the radio waves. Apparently the effect is connected with the cold and warm front and other inversion conditions in the changing troposphere. Observations on the intensity of signals from nearby broadcasting stations. *Am. Meteorological Soc., Bul.*, September, 1938, pages 317–319, 1 illus.

On Tropical vs. Extratropical Cyclonic Structure. M. Rodewald. Comments on Gherzi's "Constitution of Typhoons." *Am. Meteorological Soc., Bul.*, October, 1938, pages 339–341.

On Verifying Weather Forecasts. H. H. Clayton. Method of verifying forecasts is illustrated in tables derived from actual forecasts based on modern methods of forecasting. *Am. Meteorological Soc., Bul.*, October, 1938, pages 341–343.

Weather over the Atlantic. Capt. F. Entwhistle. Meteorological problems of the North Atlantic. Abstract and discussion of Royal Aeronautical Society paper. *Aeroplane*, November 30, 1938, page 726.

Fuels and Lubricants

Defense Plan Will Require High Octane Gasoline. H. D. Ralph. Probable increase in requirements of petroleum products for the Army and Navy with reference to the effect of the increases proposed in number of aircraft for the Army and Navy, increase in flying hours, fuel and oil items in the 1940 budget estimate for the Army Air Corps and Navy needs. *Oil & Gas Jour.*, January 19, 1939, pages 8–9, 98, 5 illus.

Some Developments Relative to Crankcase-Oil Filtration. A. T. McDonald. Data showing that compounded lubricants for use in lubrication of high-speed Diesel engines have come to be regarded as indispensable and demonstrating their influence, in high-temperature operation, on engine deposits, oil deterioration, and strength and corrosion of bearing metals. Tests of filters are described leading to the conclusion that such filters remove addition agents used in compounding Diesel-engine lubricants to a surprising degree and therefore are detrimental in such applications. Test results on the absorbent-type filter utilizing cotton fiber, yarn, waste or other such materials as their filtering medium show that this type will remove materials of considerably smaller particle magnitude. *S.A.E. Jour. (Trans.)*, January, 1939, pages 23–28, 7 illus., 4 tables.

Tetraethyilead Susceptibilities of Gasoline. L. M. Henderson, W. B. Ross, and C. M. Ridgway. Doctor treatment versus caustic washing. Experimental evidence presented shows that, when gasolines are treated with sodium plumbite and sulfur, they require more tetraethyl lead to produce a given octane value than do those treated with sodium hydroxide alone and similarly, more than do those which are thoroughly scrubbed with caustic and subsequently treated with sodium plumbite and sulfur. Differences in quantity of tetraethyllead required are related qualitatively to the amount of mercaptan sulfur removed by the caustic washing. *Industrial and Engineering Chemistry, Ind. Ed.*, January, 1939, pages 27–30, 6 illus., 3 tables.

Bearings

The Possibilities of Silver-Rich Alloys as Bearing Materials. R. W. Dayton. Silver as a bearing alloy for aircraft engines. Only frictional properties of silver and its alloys were tested since these are the primary criteria of whether or not an alloy is a bearing metal. Test for frictional properties and frictional results are described. Tables show relation between engine and amsler tests on three standard bearing materials, effect of silver purity on seizure pressure; relative deleterious effects of various additions to silver on resistance to seizure, effect of shaft finish on fractional properties of three bearing metals, and increase of oiliness obtained by alloying silver and by blending oil.

Discussion by G. A. Zink of Allison Engineering Company included. *Metals & Alloys*, December, 1938, pages 323–328, 8 illus.

Self-Oiling Brushes. Oilite self-lubricating bronze bearings. Oilite is a porous bronze material impregnated with lubricating oil of appropriate quality so that the pores within the metal act as an oil reservoir and at the same time deliver a continuous film of oil to the bearing surface by capillary and syphonic action. Bearings have been fully approved by the British Air Ministry for loads up to 3000 lb./sq.in. for intermittent and oscillating movements. They are used on flaps and aileron controls and as shim plates and washers on the DeHavilland variable-pitch propeller and engine controls. Brief note. *Aeroplane*, January 18, 1939, page 86.

Engine, Fuel and Lubricant Testing

Fundamentals of Testing and Evaluating Liquid Fuels. W. Lindner. Methods for direct testing of fuels in engines. Ignition process in Diesels and detonation in Otto-cycle engines; relation between ignition lag and chemical composition of fuel; octane and cetane numbers; test methods for Otto and Diesel fuels; simplified test methods for Diesel fuels; influence on test results for Diesel fuels; judging combustion properties; direct test method; evaluation according to relation of hydrogen content to carbon content; evaluation according to physical characteristics; testing of ignition value; and comparison of test methods. *V.D.I.*, January 7, 1939, pages 25–32, 24 illus.

New Gas Volumemeter for Determination of Gas Entering the Crankshaft Housing. W. Glaser. New apparatus for recording small volumes of gas and small gas pressures was developed by the D.V.L. for measurement of combustion gases entering the crankshaft housing. Compared with instruments previously used, the new apparatus permits better observation of the packing effect of piston rings. Description of apparatus and test results. D.V.L. report F.B. 943. *A.T.Z.*, December 10, 1938, pages 616–620, 7 illus.

A Proposed Test for Diesel Fuels. Method provides for use of the C.F.R. Diesel-fuel testing unit. Ignition quality is to be measured by coincidence-flash fixed-delay method using neon lights located on the periphery of the flywheel and operated by contact points on the combustion and injection indicators. Description of method. Abstract from A.S.T.M. report. *Automotive Industries*, February 4, 1939, pages 141–142.

A Simple Method for Observing Combustion Timing in Compression-Ignition Engines. S. G. Bauer. Method of finding the commencement of combustion in the engine consists in observing the flame directly through a stroboscopic device. A 5-mm.-diameter quartz window is fitted in the indicator passage of the engine. Light passing through it is thrown on to the flywheel rim by a small mirror. Another mirror fixed on the flywheel passes a fixed scale marked in degrees of crank angle in the neighborhood of T.D.C., and light appears on it as a line observed from a wide range of angles. Method also enables combustion timing to be observed accurately while adjustments are made on the engine. Description of instrument. *Engineering*, January 20, 1939, page 79, 2 illus.

Test Stands for High-Altitude Research. Advantages and disadvantages of several methods of operating high-altitude engine test stands are demonstrated. A test stand with cold wind-tunnel cooling is compared with an installation provided only with cooling of the combustion air and exhaust-gas outlet. The Fiat and D.V.L. engine test stands are described in great detail with drawings. D.V.L. report. *Luftwissen*, December, 1938, pages 432–436, 5 illus.

3000 Hp. Test Houses Being Built by Wright. For production testing of engines of twice the output of the 1500-hp. double-row Cyclone, a battery of 14 test cells will be built at Wright Aeronautical Corporation to accommodate engines up to 3000 hp. and to reproduce conditions encountered in flight. Four cells are already in use. Blower connected to the carburetor air intake by a duct enables test engineers to simulate the "reaming" effect of air entering the carburetor at 200 m.p.h. It is also equipped with controls by which air fed to the carburetor may be thinned out to simulate flight at high altitudes, and heated or cooled to reproduce changes in temperature. Few details. *Aero Digest*, January, 1939, page 25, 1 illus.

Ignition Quality of Diesel Fuels. J. Rifkin. Four methods for comparable assessment of the ignition quality of Diesel fuels are considered, namely: that injection advance angles be adjusted for measurable pressure rise to begin at T.D.C.; that injection advance angles be adjusted for maximum pressure in the cycinder to take place at 12° after T.D.C.; that injection advance angles be maintained fixed for all fuels; that a "constant delay-period method" be adopted whereby all fuels are injected at the same advance angle, and that compression ratio be adjusted for measurable pressure rise to start at T.D.C.

Experiments, test equipment and results obtained at Birmingham University on the first three methods using two secondary reference fuels are described in detail. Decreasing fuel quality was associated with increasing engine delay period, increasing spontaneous ignition temperature, increasing viscosity gravity index, decreasing Diesel index, and increasing analine point. *Engineering*, January 6, 1938, pages 1–4, 13 illus.

Viscous Flow Air Meters. Ricardo Alcock viscous flow air meter, installed in the experimental engine test house of the Associated Equipment Company, is designed to eliminate serious errors arising when pulsating air flows are measured in kinetic air meters of the orifice, Venturi, and other types. Meter element is a honeycomb of long triangular passages 3 in. long and 0.017 in. in height. Within working range, flow through these passages is viscous and resistance of the element is therefore directly proportional to velocity; this fact automatically eliminates the root-mean-square error. Design, operation, calibration and pulsating flow tests. *Engineer*, December 30, 1938, page 743, 3 illus.

Engine Design and Research

Research on Increasing the Torsional Resistance of Transversely Bored Shafts by Cold Working. A. Thum and H. Weiss. Investigations sponsored by the D.V.L. and undertaken to find a method of producing transversely bored shafts with increased torsional resistance. Tests were made on 60-mm.-diameter test pieces of Cr-Ni-W steel and Cr-Ni-Mo-V steel. According to tests with stamping and with various types of form stamping, it was possible to develop a new die form. This die has the shape of a quadratic pyramid with highly rounded corners. By cold forming of the bore rim, the torsional resistance of the transversely bored shaft, in the case of the two different tempered steels could be increased from 28 to 63 percent. *A.T.Z.* December 25, 1938, pages 629–633, 15 illus., 2 tables.

Piston Rings. O. Steinitz. Some notes on loss of efficiency by friction. *Automobile Engineering*, December, 1938, page 460.

Engine Manufacture

P & W Engine Production. Plant layout of Pratt & Whitney Aircraft Division. Arrangement of departments, material storerooms, first engine

test or green run, and the grinding, milling, and drilling operations are described. *Aero Digest*, January, 1939, pages 57–59, 10 illus.

Engines

American Engines Develop Maximum Horsepower up to 1500 Meters, and Ours to 5000 Meters. J. R. Pierrot. Quality of French engines, especially the Gnôme Rhône, is compared with that of Pratt and Whitney and Wright engines. Opinions expressed by M. Blanc, Chief Engineer of the Gnôme Rhône concern, after his return from a visit to the United States, are quoted regarding new developments found there, progress in metallurgy and machine tools. *Les Ailes*, December 22, 1938, page 7.

The Bi-Rotary "Mawen" Engine. Mawen radial engine in which cylinders revolve within a fixed ring carrying inlet and exhaust valves and ignition. Five-cylinder 20-hp., seven-cylinder 75-hp. and nine-cylinder 150-hp. models have been built. Seven-cylinder 350-hp. placed in a ring of 1.10 meters diameter and a 14-cylinder double-radial 700-hp. with two rings also announced. Short description of first three models and general design. *Les Ailes*, January 5, 1939, pages 7–8, 2 illus.

An Engine with Rigid Connecting Rods. M. Victor. New Varcin four-cylinder horizontally-opposed 70-hp. engine having rigid connecting rods. Transformation of motion is obtained by rack gear for displacing the pistons in one direction and the other, and slot links for reversing the movement which permit passing progressively from one course to the other without rough accelerations and also to receive the pressures from explosion at T.D.C. in the transformation into work. Long description with drawings of the double pinions and operation of the reversing slot links. Design is said to improve thermodynamic and mechanical efficiency of engines at the same time reducing their space by half. *Les Ailes*, January 5, 1939, pages 8–9, 7 illus.

A German Air-Cooled Vee Twelve. Germany's geared and supercharged aircooled inverted-vee 12-cylinder engine, produced by Argus, has passed its official 200-hour type test. Maximum power at sea level and at 9850 ft. is 360 hp. at 3000 r.p.m. Take-off power 450 hp. at 3250 r.p.m. Weight dry 660 lb. Short description, characteristics, performance. *Flight*, December 1, 1938, page 496c, 1 illus.

German Aero Engine. Zuendapp inverted aircooled aircraft engine develops 50 hp. at 2300 r.p.m. from four cylinders, 122-in. displacement. Compression ratio 6.2 allows use of ordinary fuels. Maximum output 55 hp. at 2550 r.p.m. Fuel consumption 0.48 to 0.53 lb./hp.-hr., one U.S. gal. of oil being good for 650 miles in the air. Description. *Automotive Industries*, January 14, 1939, page 55, 2 illus.

The Napier Dagger VIII. Increase of 200 hp. and a rise in rated height have resulted from improvements in the Napier-Halford Dagger VIII now in large-scale production. Increased fin area, double-entry "intermediate-altitude" supercharger, and provision for constant-speed propeller are other improvements. Unit is characterized by 24 small air-cooled cylinders arranged in the form of an H, high operational speed and compression ratio, small frontal area, and high output from small cylinder capacity (59 hp./liter maximum). Engine has an "intermediate-altitude" double-entry supercharger and maximum output of 1000 hp. at 8750 ft., rated output being 925 hp. at 9000 ft. Long description with two-page cutaway drawing showing location of parts and accessories, installation drawing and photographs. *Flight*, January 12, 1939, pages 38e-38h, 39, 7 illus., 1 table.

Long description, performance curves, and drawings illustrating location of parts and accessories in engine, installation features and intricacy of inside works of timing case and supercharger unit. Photographs show British-Thompson distributor specially developed for this engine and propeller shaft designed for constant-speed DeHavilland propeller. *Aeroplane*, January 11, 1939, pages 46–50, 10 illus.

Power in Paris. Brief preliminary review of engines exhibited at the Paris Aero Show. *Flight*, December 1, 1938, page 496, 5 illus.

Some Trends in Engine Design. Only startling departure from conventional design among bigger units is the 2000-hp. Hispano-Suiza engine developed in two forms, the 82 and 90, the former designed for concentric opposite-revolving propellers. (Twenty-four cylinders arranged in four banks of six; two crankshafts; two centrifugal superchargers each serving 12 cylinders; twelve carburetors; cylinder capacity 72 liters; compression ratio 7:1; dry weight 2200 lb.; Type 90 weight 2160 lb.)

Lorraine Sterna 12-cylinder vee 900-hp. engine has an extension shaft and oppositely-rotating propellers, direct injection in conjunction with use of a planiol supercharger and shell gun and powers the Koolhoven FK.55.

Few details also of the following: new Rolls-Royce Merlin X (two-speed supercharger, new ratings on 100-octane fuel for take-off and altitude), and Merlin R.M.2M (1285-hp. at 9500 ft., 1320 hp. for take-off, rated on 100-octane fuel) and other Rolls Royce engines. Hispano-Suiza 12Ybrs fitted with three-speed supercharger giving 920 hp. at 32,800 ft. Daimler Benz D.B. 600. Bristol Taurus 14-cylinder sleeve-valve (maximum output over 1000 hp.). New Sidelley Cheetah XI. Napier Dagger VIII (1000 hp. at 8750 ft.). Wright Cyclone G.102-A. *Flight*, December 8, 1938, pages 528c-528d, 529-530, 9 illus.

Aero-Motors at the Paris Aero Show. Aircraft engines exhibited are briefly described (or referred to in some cases) as follows: Armstrong-Siddeley Cheetah XI 485-hp. Argus As. 410 A-1 450-hp. 12-cylinder. Bloch 4A-1 95 to 100-hp. 4-cylinder inverted inline, and 6B-1 180 to 200-hp. 6-cylinder inverted inline. B.M.W. 132 880-hp. 9-cylinder radial. Bristol Taurus two-bank 14-cylinder sleeve-valve 1075-hp. Bramo-Fafnir 1000-hp. geared and supercharged 9-cylinder radial. Daimler-Benz D.B. 600 1000-hp. 12-cylinder inverted liquid-cooled and D.B. 602 1200-hp. 16-cylinder water-cooled four-stroke Diesel for airships. DeHavilland Gipsy Twelve, Six Series II, Major and Minor. Farman 9 EBR 250-hp. 9-cylinder radial, and types of superchargers exhibited. Gnôme Rhône 14-N-50 1500-hp. 14-cylinder twin-row radial with two-speed supercharger, and 14-M 750-hp. 14-cylinder radial of small diameter for high-speed fighters. Hirth HM. 512B 450-hp. 12-cylinder inverted-vee. Hispano-Suiza 24.H 2400-hp. 24-cylinder liquid-cooled H-type and engines previously exhibited. Jalbert 4-cylinder inline liquid-cooled. Lorraine Sterna Type III 900-hp. 12-cylinder water-cooled upright vee in two versions and Algol 120 600 hp. 9-cylinder radial in two versions, with solid injection or with carburetor. Sirius 1200-hp. 14-cylinder twin-row radial. Lycoming R-680-D5 260-hp. radial, and 50-hp. light-plane flat 4-cylinder. Minié flat-four 70-hp. Napier Dagger VII 1000-hp. Persey II 45-hp. flat-four. Potez 3B 70-hp. three-row radial, 8D 350-hp. inverted 12-cylinder, and 12D 450-hp. flat motor. Pratt-Whitney 800-hp. Twin Wasp Junior. P.Z.L. Major 130-hp. 4-cylinder inline installed on the P.Z.L. Wyzel trainer, and P.Z.L. new type of 8-cylinder inverted-vee aircooled shown in the P.Z.L. Wilk and said to be a secret design of the Polish Air Ministry. Regnier R.6 supercharged 250-hp. 6-cylinder inverted aircooled, unsupercharged R.6, and three 4-cylinder inverted inline. Renault 1000-hp. two-row 14-cylinder radial and smaller models. Rolls-Royce Merlin X and R.M.2. S.M. engines. Salmson 9 ADr 70-hp. geared version of the radial, and other models exhibited. Twelve Walter models. Curtiss-Wright Cyclone GR-1820-G-102-A 1100-hp. engine. A Bristol Hercules power egg illustrated "is the Company's interpretation of the scheme for making powerplants interchangeable at the back mounting bolts." *Aeroplane*, November 30, 1938, pages 717–720, 722, 9 illus.

Progress in German Aircraft Engine Design. Argus As. 410 12-cylinder inverted-vee aircooled high-altitude aircraft engine develops 380 hp. at 3000 r.p.m. at 2.6 km. altitude and 450 hp. for take-off. Weight 0.65 kg./hp. Fuel consumption 255 g./hp.-hr. Hirth HM.512 12-cylinder inverted-vee aircooled engine. The model 512A develops 400/360 hp. and the model 512B for high-altitude operation develops 450 hp. at 3100 r.p.m. for take-off and 390 hp. at 3000 r.p.m. at 2.3 km. altitude. Weight 0.68 kg./hp. Fuel consumption 220 g./hp-hr.

Long descriptions of both engines with performance curves and characteristics. Parts of the supercharger of the Argus 410 are illustrated. *Luftwissen*, November, 1938, pages 411–415, 14 illus.

Table of Soviet Engines. Characteristics and output are given for thirty-two Soviet engines. Largest is the AM-34 PH 1250-hp. engine designed in 1936–37. Latest models are of 1936–37 design. *L'Aérophile*, October, 1938, page 232, 1 table.

Parts and Accessories

For Better Starting. Rotax low-tension energy transfer booster coil system used in conjunction with the Napier Dagger engines. System employs a separate induction coil connected with the Napier Dagger engines. System employs a separate induction coil connected with the magneto primary and using it as a transformer. It supplies it with alternating impulses of approximately 200 volts. Coil has an automatic magnetic interrupter. Short description. *Flight*, January 12, 1939, page 36, 1 illus.

The New Farman Supercharger Having Two and Three Drive Gears. M. Victor. New type of clutch mechanism in the drive of the Farman centrifugal superchargers and hydraulic control are described. Parts of the drive as well as a cross section of the engine are illustrated in drawings. *Les Ailes*, December 29, 1938, page 8, 1 illus.

Szydlowski-Planiol Centrifugal Supercharger. A. Metral. Szydlowski-Planiol formulas are given for the predetermination of the performance of a supercharged engine. Principles and design of the Szydlowski-Planiol supercharger are described in detail. It was developed for scavenging their two-cycle Diesel engine but the designers improved the supercharger efficiency as much as possible and adapted it to requirements of four-cycle gasoline engines. Supercharger has been used on the Hispano-Suiza 12 Ygrs engine. Results of tests are given and discussed in detail. Long article. *L'Aéronautique*, December, 1938, pages 1–10, 12 illus., 1 table.

Elastic Mountings for Radial and Inline Engines. M. A. Julien. Dynaflex mounting for protecting airplane nacelles from the periodic forces produced by the rotation of engines and propellers. Mountings for both radial and inline engines are discussed. *La Technique Aéronautique, Sup.*, 4th Quarter, 1938, 2 pages, 7 illus.

In the Rotax Range. Rotax operating motor specially designed for operation of the controllable gills on the cowlings of radial aircraft engines, and Rotax-Eclipse motor-driven vacuum pump Type B-2A, designed for operation of flying instruments. Pump speeds up the gyros of the instruments quickly when motors are started up and thus instruments are fully sensitive at the take-off when they may be wanted urgently. Short descriptions. *Aeroplane*, January 18, 1939, page 86, 2 illus.

Aircraft Radio

Aero Radio Digest. Six radio-controlled model airplanes purchased by the Government from Reginald Denny Industries for use in target practice. Finch Telecommunication's new method of radio facsimile transmission between aircraft and ground. Two new Universal "Aircrafter" types S and M microphones for use in closed cabins and open cockpits, respectively. Five additional Bendix TG-6A 400-watt airline communication transmitters purchased by American Airlines. Air-Track's Stark position finder adopted as standard equipment on all ships operated by Pennsylvania Central Airlines. Short descriptions. *Aero Digest*, January, 1939, page 77, 3 illus.

New MacWhyte Designs. New stainless-steel tapered "spike" antenna, stainless-steel terminals of new alloy, and special cable slings. Brief reference only. *Western Flying*, December, 1938, page 30.

A New Ultra-Short-Wave Receiver. Marconi AD.66 special receiver is used to receive signals of any short-wave approach beacon transmitter and is designed for simplicity of operation. It has only one tuning control, and is subdivided into six separate units, including the main beacon and marker beacon receivers with their aerials, a L.F. magnifier unit, visual indicator, control unit with headphones, and a special H.T. battery. Short description. *Flight*, December 8, 1938, page 536.

Radio Test Procedure for CAA Type Certificates. H. W. Roberts. Approval procedure; mechanical construction requirements; emphasis on the interchangeability of units and their component parts; provisions for guarding against vibration effects; color-coded wiring; electrical design; and the humidity, temperature, spray, vibration, orientation, drop and pressure tests. *Aero Digest*, January, 1939, pages 70, 73, 4 illus.

Aviation Radio. D. Fink. Taylor Airphone single-unit transmitter-receiver for private aircraft. New 75-Mc. beacons ervice and 75-Mc. receivers installed throughout the American Airlines fleet, and Western Electric 27A receiver for 75-Mc. marker. Stark position finder used on Penn Central system. Aviation Radio AVA-24A antenna change relay intended primarily for send-receive switching, and loading coil AVA-39 for connecting transmitter to fixed receiving antenna for short-distance transmission from the ground. *Aviation*, January, 1939, page 38, 1 illus.

A Loop Direction Finder for Ultra-Short Waves—Waverange 6–11 Meters. H. G. Hopkins. Ultra-short-wave direction finder of rotating-loop type incorporates a supersonic heterodyne receiver and is suitable for use at a fixed station or in the field. Means of extending waverange of the receiver down to 6 meters are indicated. Under favorable conditions a bearing with a swing of $\pm 5^\circ$ is obtainable on a vertically polarized emission of field strength of 2 microvolts per meter. *Wireless Engr.*, December, 1938, pages 651–657, 6 illus.

New Radio Apparatus Uses Waves Only 4 Inches Long. "Klystron" ultra-short-wave radio apparatus invented by S. Varian of Pan American Airways, and developed at Stanford University, sends and receives on wave lengths as low as 10 cm. at efficiencies not hitherto attained. The rhumbatron, developed by W. W. Hansen, is applied to radio communication for airplanes. Brief note. *Science News Letter*, February 11, 1939, page 89.

Reduction in Night Error in Radio Direction Finding Installations for Airports. Advantages of the Adcock radio direction finding method. Discussion and diagrams. *E.T.Z.* January 5, 1939, page 14, 3 illus.

Book Reviews

Elementary Airplane Structural Analysis by Graphic Methods, by JAMES P. EAMES, Aviation Press, San Francisco, 1938; 180 pages, $3.00. (Loose leaf lithographed.)

This book is a simplified text dealing with the methods of stress analysis of airplane structures within reach of the aeronautical engineering student and the aircraft factory draftsman.

The first chapter is a review of elementary graphics and mechanics. There follow chapters on the characteristics of wood and metal airplane members, airworthiness requirements, fuselage structural analysis, wing truss structural analysis, and structural analysis of control members.

Appendices treat various specialized subjects, such as stagger loads, the equation of three moments, the method of least work.

A typical examination and a questionnaire are given at the end along with a glossary of terms.

The selected illustrative design problem which is projected throughout the latter chapters treat features of the analysis of a framed biplane structure. The biplane arrangement was selected as it represents a more complicated structure than the monoplane type, and the student with a knowledge of the principles can easily pass to the monoplane analysis.

The many figures are excellent and the description of the methods is well done. Although the treatment is not always rigorous the scope and general methods are given.

Elements of Aviation, Part I; World Wide Broadcasting Foundation, Boston, 1939; 44 pages.

This is one of two pamphlets which are to be used as texts by those who listen to a series of lectures on aviation which are to be broadcast by the World Wide Broadcasting Foundation in WIXAL's "University of the Air" presentations. Captain Hilding N. Carlson, head of Brown University's Department of Aeronautical Engineering, has prepared the lectures which will be broadcast at 8:30 p.m. E.S.T. on Fridays on 6.04 megacycles.

The course is carefully prepared and well illustrated and should render a helpful service. The foundation is a non-profit organization which has the support of many leading scholars.

Aeronautics Simplified, by ERNEST G. VETTER; Foster and Stewart Publishing Corporation, Buffalo, 1939; 150 pages, $1.50.

Plane Fundamentals for Flyer's License; BERT A. KUTAKOFF; Power Publishing Company, Newark, 1938; 112 pages, $1.50. (Lithographed.)

Both of these books cover substantially the same ground. Both are compilations of questions likely to be asked the candidate for a pilot's license along with more or less complete answers. Both devote about the same number of pages to technical features of airplanes, engines, meteorology, navigation. In common with all "question and answer" books, these should not be regarded as textbooks, but merely as useful guides in correlating the information gained by reading standard books on the subjects listed. The second adopts what seems to be the preferrable procedure of asking fewer questions but going into greater detail in the answers, and making use of a larger number of explanatory diagrams.

The first book includes a short chapter on the "Flight Test," giving some of the reasons for candidates failure to pass in the various maneuvers.

Both books contain a chapter on questions concerning Air Traffic Rules. The first, being the more recent, is based on the Civil Air Regulations, while the latter is based partly on Air Commerce Regulations and partly on the amendment to the Civil Air Regulations of March, 1938.

Dedication of the Wright Brothers Home and Shop in Greenfield Village; The Edison Institute (privately printed).

It is a pleasure to receive a book as beautifully designed and printed as this memento of the dedication at Dearborn. The Edison Institute has given permanence to several of the interesting addresses made on that occasion. Dr. George W. Lewis gives his interpretation of the contributions of the Wright Brothers to Aeronautical Science and Engineering; Col. Frank P. Lahm tells of his early associations with them; Walter Brookins, their first civilian student, gives his impressions of shop work and flight instruction; Griffith Brewer tells of his meeting with Wilbur Wright in Europe, and William J. Cameron, in his unique manner, eulogizes the epic achievement.

Here may be found authoritative and accurate impressions of the greatest historical event in aviation.

Appreciation is due Henry Ford for his efforts in preserving not only the home and workshop of the Wright Brothers, but also the dedication ceremonies in Greenfield Village on the seventy-first anniversary of the birth of Wilbur Wright.

The World Airways, by ROBERT FINCH; University of London Press, Ltd., 1938; 224 pages, 5s.

There has long been a demand for a book in which information regarding the airlines of the world could be found. This book fills that need exceptionally well. It gives an historical summary of the airline development in all the leading countries of the world. It tells of the routes covered, not by maps and time tables, but by informed comment which is interestingly informative.

As the writer of this review has had exceptional opportunities for studying air transport in many countries he was perhaps supercritical in his reading. Until he came to the chapters on the airlines in the United States and South America he found the contents not only accurate but obviously the result of careful observation and checking.

The author gives credit in the preface to the representative in London of one of the airlines of the United States for editing the chapter dealing with the great airways system in the United States. While this chapter will not affect the value of the book for readers in the United States it would be well if in the next edition Mr. Finch would secure a less partial adviser who would remove some of the queer observations and inaccuracies and would not confine the description of the largest airline system in the United States to a paltry five lines. It would also be advisable to have the chapter on Latin American airlines checked; the history of the famous SCADTA airline of Colombia is not even mentioned.

The book is so valuable as a reference work that the above suggestions are made to be helpful rather than to detract from the splendid editing as a whole. Any airline executive, any travel agent, or any traveler who is planning an international air trip will find in this book indispensible information on air transport throughout the world.

LESTER D. GARDNER

Sir Alan Cobham's Book of the Air, edited by SIR ALAN COBHAM, written by R. S. LYONS; Blackie and Son, Ltd., 1938; 173 pages, 5s.

No one in any country has done more to popularize aviation than "A. J." as he is called by friends who knew him before he was knighted for his epic flight to Australia and back to London. He is a born promoter. Everything he has done he has turned to the advancement of aviation. Those in the United States

Corrosion and Protective Coatings

The Protection of Metal Surfaces. T. P. Hoar. Protection by alloying additions to metal, and protective nonmetallic and metallic coatings. Selective oxidation; oxide films on aluminum; nonmetallic coatings on magnesium; anodic coatings on tin; hot-dipped coatings; electrodeposited coatings and other metallic coatings; protection against specific circumstances, testing methods for metallic coatings; and modification of the corrosive medium. *Metal Industry*, January 13, 1939, pages 83–90, 6 illus.

Iron and Steel

Internal Stresses in Castings. C. W. Briggs. Stresses in cast iron; internal stresses in cast steel; contraction stresses; stress centralization; and magnitude of stresses at hot tearing temperatures and at room temperature. *Welding Jour., Welding Res. Sup.*, January, 1939, pages 22–27, 8 illus.

Shearing, Blanking, Drawing, Spinning, Forming, and Riveting of Stainless Steel. Recommendations regarding these processes as applied to stainless steel. From Republic Steel Corporation booklet entitled "The Fabrication of Republic Enduro Stainless Steel." *Iron Age*, February 2, 1939, pages 37–41, 6 illus.

Non-Ferrous Alloys

Age Hardening of Duralumin. M. Cohen. Basic aging mechanism involves a preprecipitation stage as well as actual precipitation. It is believed that the preprecipitation stage is a process of nucleus formation in preparation for the precipitation of $CuAl_2$. When precipitation occurs, it does not take place uniformly. Localized precipitation sets in first along the grain boundaries, and this is ultimately followed by general precipitation within the grains. Tests and results described. A.I.M.E. paper. *Metal Industry*, December 30, 1938, pages 629–633, 6 illus.

Composition and Properties of Cupaloy in the "Time Capsule." P. H. Brace. Heat treatment for hardening and properties of Cupaloy. *Metals & Alloys*, November, 1938, pages 311–313, 6 illus., 4 tables.

Extraction, Properties and Fields of Application of Electrolytically Purified Aluminum. H. Roehrig. According to the three-layer method developed on the fundamental principles originated by A. G. Betts, aluminum of very high purity can be produced. Characteristics of this metal of more than 99.99 percent aluminum opens fields of application so far denied to other metals. Electrolytical refining of aluminum by the Betts and Hoopes methods is described and the properties of purified aluminum and of the alloys manufactured from them, as well as applications, are discussed in detail. *V.D.I.*, January 7, 1939, pages 33–39, 7 illus., 4 tables.

Light Alloys for Aircraft. H. Sutton. Failures under steady stress and corrosion, spot welding of light alloys, and light-alloy rivets used in aircraft construction. Discussion following the paper and author's reply are included. *Metal Industry*, December 30, 1938, pages 637–640, 6 illus.

Riveting

Explosive Riveting. Explosive charge, according to rivet size of 2.6 to 6 mm. diameter, weighs 4 to 25 mg. and is such that by heating after 2 to 3 seconds it explodes at approximately 130° temperature. Rivet warmer with conical point of silver or aluminum is placed on the rivet head from the outside. Resistance to shear of a riveted joint made with explosive rivets is approximately 15 percent less than that of the conventional riveted joint, since the material loses strength as a result of heating. Shearing strength of the rivet corresponds to that of the conventional rivet. Short abstract of article by P. Nemitz in Heinkel publication, 1938, No. 4, page 125, and of another by O. Butter, "Werkstattstechnik," 1938, No. 21, page 465. *V.D.I.* December 24, 1938, pages 1492–1493, 2 illus.

Welding

Effect of Aluminum on the Welding of Steel—Review of Literature to July 1, 1937. W. Spraragen and G. E. Claussen. Welding carbon-aluminum steels (filler rods, aluminum killed steel, high iron-aluminum alloys, forge welding, resistance welding, flame cutting); welding Nitralloy; welding Cr-Al heat-resisting steels; and suggested research problems. *Welding Jour., Welding Res. Sup.*, January, 1939, pages 8–11.

Recent Advances in Resistance Welding. L. B. Hunt. Spot, seam, butt and flash welding of aluminum alloys, magnesium alloys, and copper and nickel and their alloys.

Second article by H. W. G. Hignett, entitled "Fusion-Welding Non-Ferrous Metals," stresses the need for stimulating fundamental research, and a third, "Progress in Soldering and Brazing" by C. L. Ashby describes new joining methods and materials. *Metal Industry*, January 13, 1939, pages 69–73, 74–76, and 77–81, 13 illus., 1 table.

Some Present-Day Problems of Strength in Structural Welding. G. Bierett. Sensitivity of steels to welding; tests for sensitivity to welding; shrinkage stresses and other sources of danger; shrinkage stresses in welded girders; and increasing the quality of welded structures. Translated from German. *Welding Jour., Welding Res. Sup.*, January, 1939, pages 17–21, 7 illus.

Plastics

A Jointing Problem Tackled. New Bakelite F.5522 is based upon the fact that while the plastic material is being pressed it is capable of adhering to wood. Bakelite core is faced with wood and as the synthetic resin bonding material does not penetrate to the outer surface of the wood, the latter retains its ability to be joined to a wooden member by any well-tried gluing process. F.5522 has a high bearing strength (25,000 lb./sq.in. permissible loading). Brief note. *Flight*, January 12, 1939, page 36, 1 illus.

Plastometry of Synthetic Resins. R. Houwink and P. N. Heinze. When testing the value of resins, especially the hardening of synthetic resins, the two properties to be given most consideration are hardness (weakening point) and the hardening velocity. New apparatus to measure these properties, particularly the Schopper-Houwink plastometer, is described. Experimental results are discussed with their technical and scientific applications. *Industrial and Engineering Chemistry, Anal. Ed.*, December, 1938, pages 680–683, 10 illus., 2 equations.

Wood-Faced Laminated Material. New material developed for the specific purpose of strengthening wood members in aircraft construction has been introduced by Bakelite, Ltd. and is intended for use where ends of members are subjected to heavy shearing or bearing forces. This material is a wood-faced laminated sheet so constructed that adhesion between wood face and core of Bakelite material is greater than that of the shear strength of the wood, while wood surface itself is unaffected by any penetration of the synthetic resin bonding material. Example of use is that of joining wing spars to the fuselage. When inserts are incorporated strength of joint is greatly improved. Short note. *Engineer*, December 30, 1938, page 742, 1 illus.

Progress in the Field of Synthetic-Resin Gluing Processes. W. Kuech. Among the large number of binding agents with synthetic-resin bases used in aircraft construction, the methods of most importance are the Tegofilm in the production of plywood and veneers by heated gluing, and the gum copal gluing for additional working of materials into structural parts by the cold glue method. Whereas development of the Tegofilm may be regarded as practically completed, various improvements have been recently suggested in the working of gum copal glues and are discussed here.

New and improved method for the use of binding agents of urea-formaldehyde resins is described. By development of gum copal cold-glued powder, the limited storing properties of the liquid gum copal glue are eliminated. Gum copal glue powder, the gum copal gluing method used at the Buecker aircraft plant, Klemm gluing method, strength of glued joints at high temperatures and high humidity, and gum copal films are discussed. *Luftwissen*, December, 1938, pages 427–431, 9 illus., 3 tables.

Protein Plastics from Soybean Products. G. H. Brother and L. L. McKinney. Seventy commercially available plasticizers were tried with formaldehyde-hardened soybean protein. Polyfunctional alcohols gave positive results as plasticizing agents and of these ethyl glycol was best. Primary monohydric alcohols, esters, ketones, and oils gave most definitely negative results. Oleastearates, in mixture with ethylene glycol, reduced water absorption more than any other agent tried. Tests and results. *Industrial and Engineering Chemistry, Ind. Ed.*, January, 1939, pages 84–87, 2 illus., 3 tables.

Rubber

The Mechanical Characteristics of Rubber. F. L. Haushalter. Behavior as an engineering material in tension, compression, shear and torsion. *India Rubber World*, January 1, 1939, pages 39–42, 50, 8 illus., 2 tables.

Rubber as a Load-Carrying Material. F. L. Haushalter. Rubber as a load-carrying and structural material, and why it is best to limit stresses and strains in the rubber structure to definite values when applied in this manner. Latex, raw rubber, and the structure of rubber, theoretical and otherwise are discussed. Limitations for the proper use of rubber are determined by long-time creep or slip in the structure which, in turn, is related directly to the magnitude of stress and distortion in the material. Vucanized rubber is practically incompressible, and, when properly confined, can be loaded safely to terrific pressures just like any fluid. *S.A.E. Jour.* (*Trans*), January, 1939, pages 15–22, 18 illus.

Miscellaneous Materials

A New De-Greaser. Brown Gunk DP hydro degreasing solution does not leave an oily film, will not harm paint or fabric, is noncorrosive and perfectly safe to handle and does not vaporize. It can be applied cold and needs no equipment or tedious preparation. *Aeroplane*, January 18, 1939, page 87.

Results of Tests of the Use of Hemp Cable for Towing of Aircraft. Blechschmidt and Hohenner. Test results discussed. *Luftwissen*, December, 1938; pages 443–444, 3 illus.

This Year We Honor. New products that became commercially available in 1938, covering materials and instruments for their testing. *Industrial and Engineering Chemistry, Ind. Ed.*, January, 1939, pages 12–17, 3 illus.

Material Research Discussed at the Lilienthal-Gesellschaft for Aeronautical Research. Research on duralumin, deep-drawing sheets, manufacture of alloys, heat hardening, magnesium and aluminum-magnesium alloys, crankshaft steels, valve springs from German steel, valve materials, exhaust-gas silencers, pistons, rings and cylinders, light metal welding, synthetic materials, and non-destructive testing. Reprint of special report issued July, 1938. *A.T.Z.*, December 25, 1938, pages 625–628.

Meteorology

The Design and Performance of Radio Equipment for Radio-Meteorographs. C. B. Pear, Jr. Method of approach to the problem, choice of frequency, receivers, signal paths, transmitters and batteries, and frequency stability. *Am. Meteorological Soc., Bul.*, September, 1938, pages 299–309, 9 illus.

Gustiness in Stormy Weather. H. Arakawa. Comparison of the Dines and Robinson anemometers in the Muroto typhoon. *Am. Meteorological Soc., Bul.*, September, 1938, pages 280–281, 1 illus., 1 table.

Hyperbolic Dividers for Geostrophic Wind Computations A. F. Spilhaus. Dividers designed to estimate, from spacing of the isobars, the wind travel in a given time or the wind velocity. Computation is performed automatically with great facility and one instrument can be used on a wide variety of map scales and for any latitude. *Am. Meteorological Soc., Bul.*, October, 1938, pages 351–353, 2 illus.

Isentropic Airplane Flights—A Suggestion. A. F. Spilhaus. To supplement inexpensively and easily the information of the regular aerological network and to provide data which will be of great value in demonstrating fundamental principles of the mixing processes in the isentropic surface, it is suggested that an airplane equipped with an ordinary aerometeorograph be flown along a preselected isentrope. Procedure is described. *Am. Meteorological Soc., Bul.*, September, 1938, pages 279–280.

Ice Accretion on Aircraft (Notes for Pilots). G. C. Simpson. Physics of ice accretion is discussed giving an explanation of the different forms in which ice accretion appears on aircraft. The meteorology of ice accretion which is mainly concerned with formation of clouds, formation of precipitation, and the temperature is considered. *Am. Meteorological Soc., Bul.*, October, 1938, pages 326–329.

Balloon Transmitters. I. M. Hunter. Automatic transmitter designed for fitting in a balloon used in carrying out investigations on the electrical properties of the upper atmosphere. *Wireless World*, December 29, 1938, pages 585–587, 3 illus.

The Duration and Intensity of Twilight. H. H. Kimball. Duration of astronomical and civil twilight, and the intensity of twilight. *Monthly Weather Rev.*, September, 1938, pages 279–286, 1 illus., 6 tables.

The Hailstorm of April, 1938, at Washington, D. C. "Unusual Fall of Large Hailstones at Washington, D. C.," G. Slocum. "The Formation of Irregularly Shaped Hailstones," D. L. Arenberg. "Structure of Hailstones." *Monthly Weather Rev.*, September, 1938, pages 274–277, 2 illus., 6 equations.

Hurricane of September 16 to 20, 1938. Tropical storms in New England; the hurricane of 1938 at sea; hurricane in coastal areas and in New England; destructive effects of the hurricane; inundation damage and loss of life; and warnings. *Monthly Weather Rev.*, September, 1938, pages 286–288.

On the Use of Vertical Cross Sections in Studying Isentropic Flow. C. H. Pierce. Cross section constructed with isotherms of potential temperature and of condensation temperatures has the following advantages over the one drawn which uses temperature and specific humidity: it has thermodynamic significance; it roughly shows convective instability of air; slope of many isentropic surfaces is shown and, because fronts follow isentropic surfaces, position and slope of fronts which cut the cross section plane can be identified. *Monthly Weather Rev.*, September, 1938, pages 263–267, 7 illus.

A Practical Method for Computing Winds Aloft from Pressure and Temperature Fields. E. M. Vernon and E. V. Ashburn. Method for determining what upper winds should prevail at a given moment, past or present, by both qualitative and quantitative consideration of the distribution of pressure and temperature. It is supposed that the wind at any level in the upper air is directly related to the distribution of pressure at that level by the gradient wind equation. The well-known equation expressing pressure-height-temperature relation is accepted as the fundamental concept necessary for determination of pressures in the free air and therefore of pressure gradients at any upper level. Wind scales for measuring isobaric and thermal components, corrections for temperature and pressure, and use of the wind scales are discussed with examples. *Monthly Weather Rev.*, September, 1938, pages 267–274, 3 illus., 17 equations.

Weather Phenomena of the Colorado Rockies. R. L. Ives. From field observations in the mountain regions of Colorado, it was determined that the major portion of the state's moisture is brought in by winter cyclones. Summer storms of three types tend to redistribute the moisture derived from melting snow. Numerous barometric, electrical and optical phenomena of great interest but minor climatic importance are described briefly. Hypotheses explaining various major and minor phenomena are presented, and possible applications of this and further studies in aviation are suggested. *Journal Franklin Institute*, December, 1938, pages 691–755, 20 illus.

Local Forecasting of Heavy Winter Precipitation at Blue Hill. H. G. Dorsey, Jr. First issue—Study of seven great snowstorms of the winter type, 1933–38, and a study of two spring-type snowstorms. Second issue—Use of Mt. Washington data in short-term forecasting for Boston. *Am. Meteorological Soc., Bul.*, September and October, 1938, pages 281–297 and 335–339, 15 illus.

The Ohio River Flood of 1937. W. C. Devereaux. Conditions leading to the flood and flood forecasting. *Am. Meteorological Soc. Bul.*, October, 1938, pages 330–333.

On the Frequency Distribution of Sleet-Drop Sizes. H. Landsberg and H. Neuberger. Results of measurement of sleet drops during a heavy sleet storm at State College, Pa. *Am. Meteorological Soc., Bul.*, October, 1938, pages 354–355, 1 illus., 2 tables.

Studies of Tropospheric Changes and Radio Reception. R. C. Colwell and A. W. Friend. Lower region of the atmosphere (troposphere) influences the propagation of the radio waves. Apparently the effect is connected with the cold and warm front and other inversion conditions in the changing troposphere. Observations on the intensity of signals from nearby broadcasting stations. *Am. Meteorological Soc., Bul.*, September, 1938, pages 317–319, 1 illus.

On Tropical vs. Extratropical Cyclonic Structure. M. Rodewald. Comments on Gherzi's "Constitution of Typhoons." *Am. Meteorological Soc., Bul.*, October, 1938, pages 339–341.

On Verifying Weather Forecasts. H. H. Clayton. Method of verifying forecasts is illustrated in tables derived from actual forecasts based on modern methods of forecasting. *Am. Meteorological Soc., Bul.*, October, 1938, pages 341–343.

Weather over the Atlantic. Capt. F. Entwhistle. Meteorological problems of the North Atlantic. Abstract and discussion of Royal Aeronautical Society paper. *Aeroplane*, November 30, 1938, page 726.

Fuels and Lubricants

Defense Plan Will Require High Octane Gasoline. H. D. Ralph. Probable increase in requirements of petroleum products for the Army and Navy with reference to the effect of the increases proposed in number of aircraft for the Army and Navy, increase in flying hours, fuel and oil items in the 1940 budget estimate for the Army Air Corps and Navy needs. *Oil & Gas Jour.*, January 19, 1939, pages 8–9, 98, 5 illus.

Some Developments Relative to Crankcase-Oil Filtration. A. T. McDonald. Data showing that compounded lubricants for use in lubrication of high-speed Diesel engines have come to be regarded as indispensable and demonstrating their influence, in high-temperature operation, on engine deposits, oil deterioration, and strength and corrosion of bearing metals. Tests of filters are described leading to the conclusion that such filters remove addition agents used in compounding Diesel-engine lubricants to a surprising degree and therefore are detrimental in such applications. Test results on the absorbent-type filter utilizing cotton fiber, yarn, waste or other such materials as their filtering medium show that this type will remove materials of considerably smaller particle magnitude. *S.A.E. Jour. (Trans.)*, January, 1939, pages 23–28, 7 illus., 4 tables.

Tetraethyllead Susceptibilities of Gasoline. L. M. Henderson, W. B. Ross, and C. M. Ridgway. Doctor treatment versus caustic washing. Experimental evidence presented shows that, when gasolines are treated with sodium plumbite and sulfur, they require more tetraethyl lead to produce a given octane value than do those treated with sodium hydroxide alone and similarly, more than do those which are thoroughly scrubbed with caustic and subsequently treated with sodium plumbite and sulfur. Differences in quantity of tetraethyllead required are related qualitatively to the amount of mercaptan sulfur removed by the caustic washing. *Industrial and Engineering Chemistry, Ind. Ed.*, January, 1939, pages 27–30, 6 illus., 3 tables.

Bearings

The Possibilities of Silver-Rich Alloys as Bearing Materials. R. W. Dayton. Silver as a bearing alloy for aircraft engines. Only frictional properties of silver and its alloys were tested since these are the primary criteria of whether or not an alloy is a bearing metal. Test for frictional properties and frictional results are described. Tables show relation between engine and amsler tests on three standard bearing materials, effect of silver purity on seizure pressure; relative deleterious effects of various additions to silver on resistance to seizure, effect of shaft finish on fractional properties of three bearing metals, and increase of oiliness obtained by alloying silver and by blending oil.

Discussion by G. A. Zink of Allison Engineering Company included. *Metals & Alloys*, December, 1938, pages 323–328, 8 illus.

Self-Oiling Brushes. Oilite self-lubricating bronze bearings. Oilite is a porous bronze material impregnated with lubricating oil of appropriate quality so that the pores within the metal act as an oil reservoir and at the same time deliver a continuous film of oil to the bearing surface by capillary and syphonic action. Bearings have been fully approved by the British Air Ministry for loads up to 3000 lb./sq.in. for intermittent and oscillating movements. They are used on flaps and aileron controls and as shim plates and washers on the DeHavilland variable-pitch propeller and engine controls. Brief note. *Aeroplane*, January 18, 1939, page 86.

Engine, Fuel and Lubricant Testing

Fundamentals of Testing and Evaluating Liquid Fuels. W. Lindner. Methods for direct testing of fuels in engines. Ignition process in Diesels and detonation in Otto-cycle engines; relation between ignition lag and chemical composition of fuel; octane and cetane numbers; test methods for Otto and Diesel fuels; simplified test methods for Diesel fuels; influence on test results for Diesel fuels; judging combustion properties; direct test method; evaluation according to relation of hydrogen content to carbon content; evaluation according to physical characteristics; testing of ignition value; and comparison of test methods. *V.D.I.*, January 7, 1939, pages 25–32, 24 illus.

New Gas Volumemeter for Determination of Gas Entering the Crankshaft Housing. W. Glaser. New apparatus for recording small volumes of gas and small gas pressures was developed by the D.V.L. for measurement of combustion gases entering the crankshaft housing. Compared with instruments previously used, the new apparatus permits better observation of the packing effect of piston rings. Description of apparatus and test results. D.V.L. report F.B. 943. *A.T.Z.*, December 10, 1938, pages 616–620, 7 illus.

A Proposed Test for Diesel Fuels. Method provides for use of the C.F.R. Diesel-fuel testing unit. Ignition quality is to be measured by coincidence-flash fixed-delay method using neon lights located on the periphery of the flywheel and operated by contact points on the combustion and injection indicators. Description of method. Abstract from A.S.T.M. report. *Automotive Industries*, February 4, 1939, pages 141–142.

A Simple Method for Observing Combustion Timing in Compression-Ignition Engines. S. G. Bauer. Method of finding the commencement of combustion in the engine consists in observing the flame directly through a stroboscopic device. A 5-mm.-diameter quartz window is fitted in the indicator passage of the engine. Light passing through it is thrown on to the flywheel rim by a small mirror. Another mirror fixed on the flywheel passes a fixed scale marked in degrees of crank angle in the neighborhood of T.D.C., and light appears on it as a line observed from a wide range of angles. Method also enables combustion timing to be observed accurately while adjustments are made on the engine. Description of instrument. *Engineering*, January 20, 1939, page 79, 2 illus.

Test Stands for High-Altitude Research. Advantages and disadvantages of several methods of operating high-altitude engine test stands are demonstrated. A test stand with cold wind-tunnel cooling is compared with an installation provided only with cooling of the combustion air and exhaust-gas outlet. The Fiat and D.V.L. engine test stands are described in great detail with drawings. D.V.L. report. *Luftwissen*, December, 1938, pages 432–436, 5 illus.

3000 Hp. Test Houses Being Built by Wright. For production testing of engines of twice the output of the 1500-hp. double-row Cyclone, a battery of 14 test cells will be built at Wright Aeronautical Corporation to accommodate engines up to 3000 hp. and to reproduce conditions encountered in flight. Four cells are already in use. Blower connected to the carburetor air intake by a duct enables test engineers to simulate the "reaming" effect of air entering the carburetor at 200 m.p.h. It is also equipped with controls by which air fed to the carburetor may be thinned out to simulate flight at high altitudes, and heated or cooled to reproduce changes in temperature. Few details. *Aero Digest*, January, 1939, page 25, 1 illus.

Ignition Quality of Diesel Fuels. J. Rifkin. Four methods for comparable assessment of the ignition quality of Diesel fuels are considered, namely: that injection advance angles be adjusted for measurable pressure rise to begin at T.D.C.; that injection advance angles be adjusted for maximum pressure in the cycinder to take place at 12° after T.D.C.; that injection advance angles be maintained fixed for all fuels; that a "constant delay-period method" be adopted whereby all fuels are injected at the same advance angle, and that compression ratio be adjusted for measurable pressure rise to start at T.D.C.

Experiments, test equipment and results obtained at Birmingham University on the first three methods using two secondary reference fuels are described in detail. Decreasing fuel quality was associated with increasing engine delay period, increasing spontaneous ignition temperature, increasing viscosity gravity index, decreasing Diesel index, and increasing analine point. *Engineering*, January 6, 1938, pages 1–4, 13 illus.

Viscous Flow Air Meters. Ricardo Alcock viscous flow air meter, installed in the experimental engine test house of the Associated Equipment Company, is designed to eliminate serious errors arising when pulsating air flows are measured in kinetic air meters of the orifice, Venturi, and other types. Meter element is a honeycomb of long triangular passages 3 in. long and 0.017 in. in height. Within working range, flow through these passages is viscous and resistance of the element is therefore directly proportional to velocity; this fact automatically eliminates the root-mean-square error. Design, operation, calibration and pulsating flow tests. *Engineer*, December 30, 1938, page 743, 3 illus.

Engine Design and Research

Research on Increasing the Torsional Resistance of Transversely Bored Shafts by Cold Working. A. Thum and H. Weiss. Investigations sponsored by the D.V.L. and undertaken to find a method of producing transversely bored shafts with increased torsional resistance. Tests were made on 60-mm.-diameter test pieces of Cr-Ni-W steel and Cr-Ni-Mo-V steel. According to tests with stamping and with various types of form stamping, it was possible to develop a new die form. This die has the shape of a quadratic pyramid with highly rounded corners. By cold forming of the bore rim, the torsional resistance of the transversely bored shaft, in the case of the two different tempered steels could be increased from 28 to 63 percent. *A.T.Z.* December 25, 1938, pages 629–633, 15 illus., 2 tables.

Piston Rings. O. Steinitz. Some notes on loss of efficiency by friction. *Automobile Engineering*, December, 1938, page 460.

Engine Manufacture

P & W Engine Production. Plant layout of Pratt & Whitney Aircraft Division. Arrangement of departments, material storerooms, first engine

test or green run, and the grinding, milling, and drilling operations are described. *Aero Digest*, January, 1939, pages 57–59, 10 illus.

Engines

American Engines Develop Maximum Horsepower up to 1500 Meters, and Ours to 5000 Meters. J. R. Pierrot. Quality of French engines, especially the Gnôme Rhône, is compared with that of Pratt and Whitney and Wright engines. Opinions expressed by M. Blanc, Chief Engineer of the Gnôme Rhône concern, after his return from a visit to the United States, are quoted regarding new developments found there, progress in metallurgy and machine tools. *Les Ailes*, December 22, 1938, page 7.

The Bi-Rotary "Mawen" Engine. Mawen radial engine in which cylinders revolve within a fixed ring carrying inlet and exhaust valves and ignition. Five-cylinder 20-hp., seven-cylinder 75-hp. and nine-cylinder 150-hp. models have been built. Seven-cylinder 350-hp. placed in a ring of 1.10 meters diameter and a 14-cylinder double-radial 700-hp. with two rings also announced. Short description of first three models and general design. *Les Ailes*, January 5, 1939, pages 7–8, 2 illus.

An Engine with Rigid Connecting Rods. M. Victor. New Varcin four-cylinder horizontally-opposed 70-hp. engine having rigid connecting rods. Transformation of motion is obtained by rack gear for displacing the pistons in one direction and the other, and slot links for reversing the movement which permit passing progressively from one course to the other without rough accelerations and also to receive the pressures from explosion at T.D.C. in the transformation into work. Long description with drawings of the double pinions and operation of the reversing slot links. Design is said to improve thermodynamic and mechanical efficiency of engines at the same time reducing their space by half. *Les Ailes*, January 5, 1939, pages 8–9, 7 illus.

A German Air-Cooled Vee Twelve. Germany's geared and supercharged aircooled inverted-vee 12-cylinder engine, produced by Argus, has passed its official 200-hour type test. Maximum power at sea level and at 9850 ft. is 360 hp. at 3000 r.p.m. Take-off power 450 hp. at 3250 r.p.m. Weight dry 660 lb. Short description, characteristics, performance. *Flight*, December 1, 1938, page 496c, 1 illus.

German Aero Engine. Zuendapp inverted aircooled aircraft engine develops 50 hp. at 2300 r.p.m. from four cylinders, 122-in. displacement. Compression ratio 6.2 allows use of ordinary fuels. Maximum output 55 hp. at 2550 r.p.m. Fuel consumption 0.48 to 0.53 lb./hp.-hr., one U.S. gal. of oil being good for 650 miles in the air. Description. *Automotive Industries*, January 14, 1939, page 55, 2 illus.

The Napier Dagger VIII. Increase of 200 hp. and a rise in rated height have resulted from improvements in the Napier-Halford Dagger VIII now in large-scale production. Increased fin area, double-entry "intermediate-altitude" supercharger, and provision for constant-speed propeller are other improvements. Unit is characterized by 24 small air-cooled cylinders arranged in the form of an H, high operational speed and compression ratio, small frontal area, and high output from small cylinder capacity (59 hp./liter maximum). Engine has an "intermediate-altitude" double-entry supercharger and maximum output of 1000 hp. at 8750 ft., rated output being 925 hp. at 9000 ft. Long description with two-page cutaway drawing showing location of parts and accessories, installation drawing and photographs. *Flight*, January 12, 1939, pages 38e-38h, 39, 7 illus., 1 table.

Long description, performance curves, and drawings illustrating location of parts and accessories in engine, installation features and intricacy of inside works of timing case and supercharger unit. Photographs show British-Thompson distributor specially developed for this engine and propeller shaft designed for constant-speed DeHavilland propeller. *Aeroplane*, January 11, 1939, pages 46–50, 10 illus.

Power in Paris. Brief preliminary review of engines exhibited at the Paris Aero Show. *Flight*, December 1, 1938, page 496, 5 illus.

Some Trends in Engine Design. Only startling departure from conventional design among bigger units is the 2000-hp. Hispano-Suiza engine developed in two forms, the 82 and 90, the former designed for concentric opposite-revolving propellers. (Twenty-four cylinders arranged in four banks of six; two crankshafts; two centrifugal superchargers each serving 12 cylinders; twelve carburetors; cylinder capacity 72 liters; compression ratio 7:1; dry weight 2200 lb.; Type 90 weight 2160 lb.)

Lorraine Sterna 12-cylinder vee 900-hp. engine has an extension shaft and oppositely-rotating propellers, direct injection in conjunction with use of a planiol supercharger and shell gun and powers the Koolhoven FK.55.

Few details also of the following: new Rolls-Royce Merlin X (two-speed supercharger, new ratings on 100-octane fuel for take-off and altitude), and Merlin R.M.2M (1285-hp. at 9500 ft., 1320 hp. for take-off, rated on 100-octane fuel) and other Rolls Royce engines. Hispano-Suiza 12Ybrs fitted with three-speed supercharger giving 920 hp. at 32,800 ft. Daimler Benz D.B. 600. Bristol Taurus 14-cylinder sleeve-valve (maximum output over 1000 hp.). New Sidelley Cheetah XI. Napier Dagger VIII (1000 hp. at 8750 ft.). Wright Cyclone G.102-A. *Flight*, December 8, 1938, pages 528c-528d, 529-530, 9 illus.

Aero-Motors at the Paris Aero Show. Aircraft engines exhibited are briefly described (or referred to in some cases) as follows: Armstrong-Siddeley Cheetah XI 485-hp. Argus As. 410 A-1 450-hp. 12-cylinder. Bloch 4A-1 95 to 100-hp. 4-cylinder inverted inline, and 6B-1 180 to 200-hp. 6-cylinder inverted inline. B.M.W. 132 880-hp. 9-cylinder radial. Bristol Taurus two-bank 14-cylinder sleeve-valve 1075-hp. Bramo-Fafnir 1000-hp. geared and supercharged 9-cylinder radial. Daimler-Benz D.B. 600 1000-hp. 12-cylinder inverted liquid-cooled and D.B. 602 1200-hp. 16-cylinder water-cooled four-stroke Diesel for airships. DeHavilland Gipsy Twelve, Six Series II, Major and Minor. Farman 9 EBR 250-hp. 9-cylinder radial, and types of superchargers exhibited. Gnôme Rhône 14-N-50 1500-hp. 14-cylinder twin-row radial with two-speed supercharger, and 14-M 750-hp. 14-cylinder radial of small diameter for high-speed fighters. Hirth HM. 512B 450-hp. 12-cylinder inverted-vee. Hispano-Suiza 24.H 2400-hp. 24-cylinder liquid-cooled H-type and engines previously exhibited. Jalbert 4-cylinder inline liquid-cooled. Lorraine Sterna Type III 900-hp. 12-cylinder water-cooled upright vee in two versions and Algol 120 600 hp. 9-cylinder radial in two versions, with solid injection or with carburetor. Sirius 1200-hp. 14-cylinder twin-row radial. Lycoming R-680-D5 260-hp. radial, and 50-hp. light-plane flat 4-cylinder. Minié flat-four 70-hp. Napier Dagger VII 1000-hp. Persey II 45-hp. flat-four. Potez 3B 70-hp. three-row radial, 8D 350-hp. inverted 12-cylinder, and 12D 450-hp. flat motor. Pratt-Whitney 800-hp. Twin Wasp Junior. P.Z.L. Major 130-hp. 4-cylinder inline installed on the P.Z.L. Wyzel trainer, and P.Z.L. new type of 8-cylinder inverted-vee aircooled shown in the P.Z.L. Wilk and said to be a secret design of the Polish Air Ministry. Regnier R.6 supercharged 250-hp. 6-cylinder inverted aircooled, unsupercharged R.6, and three 4-cylinder inverted inline. Renault 1000-hp. two-row 14-cylinder radial and smaller models. Rolls-Royce Merlin X and R.M.2. S.M. engines. Salmson 9 ADr 70-hp. geared version of the radial, and other models exhibited. Twelve Walter models. Curtiss-Wright Cyclone GR-1820-G-102-A 1100-hp. engine. A Bristol Hercules power egg illustrated "is the Company's interpretation of the scheme for making powerplants interchangeable at the back mounting bolts." *Aeroplane*, November 30, 1938, pages 717–720, 722, 9 illus.

Progress in German Aircraft Engine Design. Argus As. 410 12-cylinder inverted-vee aircooled high-altitude aircraft engine develops 380 hp. at 3000 r.p.m. at 2.6 km. altitude and 450 hp. for take-off. Weight 0.65 kg./hp. Fuel consumption 255 g./hp.-hr. Hirth HM.512 12-cylinder inverted-vee aircooled engine. The model 512A develops 400/360 hp. and the model 512B for high-altitude operation develops 450 hp. at 3100 r.p.m. for take-off and 390 hp. at 3000 r.p.m. at 2.3 km. altitude. Weight 0.68 kg./hp. Fuel consumption 220 g./hp-hr.

Long descriptions of both engines with performance curves and characteristics. Parts of the supercharger of the Argus 410 are illustrated. *Luftwissen*, November, 1938, pages 411–415, 14 illus.

Table of Soviet Engines. Characteristics and output are given for thirty-two Soviet engines. Largest is the AM-34 PH 1250-hp. engine designed in 1936–37. Latest models are of 1936–37 design. *L'Aérophile*, October, 1938, page 232, 1 table.

Parts and Accessories

For Better Starting. Rotax low-tension energy transfer booster coil system used in conjunction with the Napier Dagger engines. System employs a separate induction coil connected with the Napier Dagger engines. System employs a separate induction coil connected with the magneto primary and using it as a transformer. It supplies it with alternating impulses of approximately 200 volts. Coil has an automatic magnetic interrupter. Short description. *Flight*, January 12, 1939, page 36, 1 illus.

The New Farman Supercharger Having Two and Three Drive Gears. M. Victor. New type of clutch mechanism in the drive of the Farman centrifugal superchargers and hydraulic control are described. Parts of the drive as well as a cross section of the engine are illustrated in drawings. *Les Ailes*, December 29, 1938, page 8, 1 illus.

Szydlowski-Planiol Centrifugal Supercharger. A. Metral. Szydlowski-Planiol formulas are given for the predetermination of the performance of a supercharged engine. Principles and design of the Szydlowski-Planiol supercharger are described in detail. It was developed for scavenging their two-cycle Diesel engine but the designers improved the supercharger efficiency as much as possible and adapted it to requirements of four-cycle gasoline engines. Supercharger has been used on the Hispano-Suiza 12 Ygrs engine. Results of tests are given and discussed in detail. Long article. *L'Aéronautique*, December, 1938, pages 1–10, 12 illus., 1 table.

Elastic Mountings for Radial and Inline Engines. M. A. Julien. Dynaflex mounting for protecting airplane nacelles from the periodic forces produced by the rotation of engines and propellers. Mountings for both radial and inline engines are discussed. *La Technique Aéronautique, Sup.*, 4th Quarter, 1938, 2 pages, 7 illus.

In the Rotax Range. Rotax operating motor specially designed for operation of the controllable gills on the cowlings of radial aircraft engines, and Rotax-Eclipse motor-driven vacuum pump Type B-2A, designed for operation of flying instruments. Pump speeds up the gyros of the instruments quickly when motors are started up and thus instruments are fully sensitive at the take-off when they may be wanted urgently. Short descriptions. *Aeroplane*, January 18, 1939, page 86, 2 illus.

Aircraft Radio

Aero Radio Digest. Six radio-controlled model airplanes purchased by the Government from Reginald Denny Industries for use in target practice. Finch Telecommunication's new method of radio facsimile transmission between aircraft and ground. Two new Universal "Aircrafter" types S and M microphones for use in closed cabins and open cockpits, respectively. Five additional Bendix TG-6A 400-watt airline communication transmitters purchased by American Airlines. Air-Track's Stark position finder adopted as standard equipment on all ships operated by Pennsylvania Central Airlines. Short descriptions. *Aero Digest*, January, 1939, page 77, 3 illus.

New MacWhyte Designs. New stainless-steel tapered "spike" antenna, stainless-steel terminals of new alloy, and special cable slings. Brief reference only. *Western Flying*, December, 1938, page 30.

A New Ultra-Short-Wave Receiver. Marconi AD.66 special receiver is used to receive signals of any short-wave approach beacon transmitter and is designed for simplicity of operation. It has only one tuning control, and is subdivided into six separate units, including the main beacon and marker beacon receivers with their aerials, a L.F. magnifier unit, visual indicator, control unit with headphones, and a special H.T. battery. Short description. *Flight*, December 8, 1938, page 536.

Radio Test Procedure for CAA Type Certificates. H. W. Roberts. Approval procedure; mechanical construction requirements; emphasis on the interchangeability of units and their component parts; provisions for guarding against vibration effects; color-coded wiring; electrical design; and the humidity, temperature, spray, vibration, orientation, drop and pressure tests. *Aero Digest*, January, 1939, pages 70, 73, 4 illus.

Aviation Radio. D. Fink. Taylor Airphone single-unit transmitter-receiver for private aircraft. New 75-Mc. beacons ervice and 75-Mc. receivers installed throughout the American Airlines fleet, and Western Electric 27A receiver for 75-Mc. marker. Stark position finder used on Penn Central system. Aviation Radio AVA-24A antenna change relay intended primarily for send-receive switching, and loading coil AVA-39 for connecting transmitter to fixed receiving antenna for short-distance transmission from the ground. *Aviation*, January, 1939, page 38, 1 illus.

A Loop Direction Finder for Ultra-Short Waves—Waverange 6–11 Meters. H. G. Hopkins. Ultra-short-wave direction finder of rotating-loop type incorporates a supersonic heterodyne receiver and is suitable for use at a fixed station or in the field. Means of extending waverange of the receiver down to 6 meters are indicated. Under favorable conditions a bearing with a swing of $\pm 5°$ is obtainable on a vertically polarized emission of field strength of 2 microvolts per meter. *Wireless Engr.*, December, 1938, pages 651–657, 6 illus.

New Radio Apparatus Uses Waves Only 4 Inches Long. "Klystron" ultra-short-wave radio apparatus invented by S. Varian of Pan American Airways, and developed at Stanford University, sends and receives on wave lengths as low as 10 cm. at efficiencies not hitherto attained. The rhumbatron, developed by W. W. Hansen, is applied to radio communication for airplanes. Brief note. *Science News Letter*, February 11, 1939, page 89.

Reduction in Night Error in Radio Direction Finding Installations for Airports. Advantages of the Adcock radio direction finding method. Discussion and diagrams. *E.T.Z.* January 5, 1939, page 14, 3 illus.

Book Reviews

Elementary Airplane Structural Analysis by Graphic Methods, by JAMES P. EAMES, Aviation Press, San Francisco, 1938; 180 pages, $3.00. (Loose leaf lithographed.)

This book is a simplified text dealing with the methods of stress analysis of airplane structures within reach of the aeronautical engineering student and the aircraft factory draftsman.

The first chapter is a review of elementary graphics and mechanics. There follow chapters on the characteristics of wood and metal airplane members, airworthiness requirements, fuselage structural analysis, wing truss structural analysis, and structural analysis of control members.

Appendices treat various specialized subjects, such as stagger loads, the equation of three moments, the method of least work.

A typical examination and a questionnaire are given at the end along with a glossary of terms.

The selected illustrative design problem which is projected throughout the latter chapters treat features of the analysis of a framed biplane structure. The biplane arrangement was selected as it represents a more complicated structure than the monoplane type, and the student with a knowledge of the principles can easily pass to the monoplane analysis.

The many figures are excellent and the description of the methods is well done. Although the treatment is not always rigorous the scope and general methods are given.

Elements of Aviation, Part I; World Wide Broadcasting Foundation, Boston, 1939; 44 pages.

This is one of two pamphlets which are to be used as texts by those who listen to a series of lectures on aviation which are to be broadcast by the World Wide Broadcasting Foundation in WIXAL's "University of the Air" presentations. Captain Hilding N. Carlson, head of Brown University's Department of Aeronautical Engineering, has prepared the lectures which will be broadcast at 8:30 p.m. E.S.T. on Fridays on 6.04 megacycles.

The course is carefully prepared and well illustrated and should render a helpful service. The foundation is a non-profit organization which has the support of many leading scholars.

Aeronautics Simplified, by ERNEST G. VETTER; Foster and Stewart Publishing Corporation, Buffalo, 1939; 150 pages, $1.50.

Plane Fundamentals for Flyer's License; BERT A. KUTAKOFF; Power Publishing Company, Newark, 1938; 112 pages, $1.50. (Lithographed.)

Both of these books cover substantially the same ground. Both are compilations of questions likely to be asked the candidate for a pilot's license along with more or less complete answers. Both devote about the same number of pages to technical features of airplanes, engines, meteorology, navigation. In common with all "question and answer" books, these should not be regarded as textbooks, but merely as useful guides in correlating the information gained by reading standard books on the subjects listed. The second adopts what seems to be the preferrable procedure of asking fewer questions but going into greater detail in the answers, and making use of a larger number of explanatory diagrams.

The first book includes a short chapter on the "Flight Test," giving some of the reasons for candidates failure to pass in the various maneuvers.

Both books contain a chapter on questions concerning Air Traffic Rules. The first, being the more recent, is based on the Civil Air Regulations, while the latter is based partly on Air Commerce Regulations and partly on the amendment to the Civil Air Regulations of March, 1938.

Dedication of the Wright Brothers Home and Shop in Greenfield Village; The Edison Institute (privately printed).

It is a pleasure to receive a book as beautifully designed and printed as this memento of the dedication at Dearborn. The Edison Institute has given permanence to several of the interesting addresses made on that occasion. Dr. George W. Lewis gives his interpretation of the contributions of the Wright Brothers to Aeronautical Science and Engineering; Col. Frank P. Lahm tells of his early associations with them; Walter Brookins, their first civilian student, gives his impressions of shop work and flight instruction; Griffith Brewer tells of his meeting with Wilbur Wright in Europe, and William J. Cameron, in his unique manner, eulogizes the epic achievement.

Here may be found authoritative and accurate impressions of the greatest historical event in aviation.

Appreciation is due Henry Ford for his efforts in preserving not only the home and workshop of the Wright Brothers, but also the dedication ceremonies in Greenfield Village on the seventy-first anniversary of the birth of Wilbur Wright.

The World Airways, by ROBERT FINCH; University of London Press, Ltd., 1938; 224 pages, 5s.

There has long been a demand for a book in which information regarding the airlines of the world could be found. This book fills that need exceptionally well. It gives an historical summary of the airline development in all the leading countries of the world. It tells of the routes covered, not by maps and time tables, but by informed comment which is interestingly informative.

As the writer of this review has had exceptional opportunities for studying air transport in many countries he was perhaps supercritical in his reading. Until he came to the chapters on the airlines in the United States and South America he found the contents not only accurate but obviously the result of careful observation and checking.

The author gives credit in the preface to the representative in London of one of the airlines of the United States for editing the chapter dealing with the great airways system in the United States. While this chapter will not affect the value of the book for readers in the United States it would be well if in the next edition Mr. Finch would secure a less partial adviser who would remove some of the queer observations and inaccuracies and would not confine the description of the largest airline system in the United States to a paltry five lines. It would also be advisable to have the chapter on Latin American airlines checked; the history of the famous SCADTA airline of Colombia is not even mentioned.

The book is so valuable as a reference work that the above suggestions are made to be helpful rather than to detract from the splendid editing as a whole. Any airline executive, any travel agent, or any traveler who is planning an international air trip will find in this book indispensible information on air transport throughout the world.

LESTER D. GARDNER

Sir Alan Cobham's Book of the Air, edited by SIR ALAN COBHAM, written by R. S. LYONS; Blackie and Son, Ltd., 1938; 173 pages, 5s.

No one in any country has done more to popularize aviation than "A. J." as he is called by friends who knew him before he was knighted for his epic flight to Australia and back to London. He is a born promoter. Everything he has done he has turned to the advancement of aviation. Those in the United States

who were fortunate enough to hear him speak with his mentor Sir Sefton Brancker agreed that they were the ablest as well as the wittiest proponents of aviation they had ever met.

This book is a natural outcome of Sir Alan's activities. As a "barnstormer" he had carried 10,000 passengers by 1919. In the succeeding twenty years he has engaged in aerial photography, started the first air taxi service in England, and pioneered air routes to Australia, around Europe and Africa. For many years, with the assistance of Lord Wakefield, he headed an educational aviation show that had certain elements in common with the American flying circus, though it was conducted in a more dignified manner. Hundreds of thousands of passengers were given their first flights, airport development was encouraged, and public interest was aroused.

The book is unique in that it gives credit to a "ghost writer"; "A. J." merely takes credit for editing it. The parts where the writer R. S. Lyons relied on the editor's memory of the early days and early pilots are the best in the book. He is generous in giving individual praise to all of the world famous pilots from Orville Wright to Wiley Post.

Other chapters give a miscellaneous treatment of many phases of aeronautics—airplane construction, air transport, parachuting, gliding, air mail, etc. The book closes with a weird guess as to aviation in the year 2038.

In his editing "A. J." must have been kind to his "ghost writer." Readers are solemnly informed that no British airliner could have a forced landing in flying over water as "there is a spare engine for such eventualities." There is no mention that Colonel Lindbergh flew the Atlantic to try to win the Orteig prize of $25,000, and no reference is made to the first flight of the N.C.4 from New York to England. However, these slips regarding American efforts are more than offset by a most gracious praise of American transport operations.

The book closes with an imaginary passenger-carrying rocket flight from New York to London in one hour. The rocket is supposed to reach the fantastic speed of 14,000 miles an hour. The "shock wave" that will be given engineers reading this chapter will probably be as great as the shock wave ahead of the rocket. But A. J.'s well-known sense of humor will come to his rescue and permit him to smile with informed readers at the futuristic imaginings of his associate.

The book reflects that insatiable optimism and courage which has brought Sir Alan Cobham fame, success, and innumerable admirers in all parts of the world.

Civil Defense, by C. W. GLOVER; Chapman and Hall, Ltd., London, 1938; 299 pages, 15s.

Dedicated to the defenseless citizens, this book gives a more complete study of every phase of air defense than has been found elsewhere in one compilation.

After a short summary of the various forms of aerial attack, the author not only discusses, but gives costs of many elements that enter into the complete defense of the citizenry, both in cities and in the country. Even to those accustomed to reading of the large sums required for air forces, it may be suprising to learn that the author estimates that it would require approximately one billion, eight hundred million dollars to protect adequately the thirty-two million citizens of England against air attack. A large proportion of the amount would be required for shelters which would be proof against heavy bombs; other shelters would have to afford protection from light bombs and splinters. Even this huge sum does not provide protection for fifteen million persons living in rural districts.

The cost and design of all types of shelters are given. From the private home to the largest factory and government buildings, some form of protection will be required. Gas masks for civilians cost about $10, but when protective clothing is required, the cost may be as high as $50 for each suit. The equipment required for use in shelters, ranging from foods to sanitary conveniences, are carefully listed. The protection of a million and a quarter animals in rural districts is a problem that presents difficulties. Horses, cattle, sheep, pigs, dogs, cats, and even pigeons and domestic pet birds all have to be considered in air protection plans. While all these measures seem far off to us in the United States, it is startling to find a book of this kind containing advertisements for much of the equipment required for air protection. Everything except insurance is listed. As yet there is no insurance of this kind available; the author believes that it is impractical to secure coverage at the present time.

With all the possibilities of danger so apparent, the author asserts that the Briton "true to his nature is exhibiting a lamentable apathy to the whole question. He quite sensibly is unmoved by the alarmist, but on the whole, he does not take the A.R.P. seriously." He states further "we will not have time to muddle through to ultimate victory. The attack from the air will not be a mere three minute raid, but a sudden intense concentration. Panic, our worst possible enemy, must not be permitted."

Views on Air Defense, by LIEUT. GENERAL N. N. GOLOVINE; Gale and Polden, Ltd., Aldershot, 1938; 100 pages, 5s.

Those who have positive convictions that there is no certain defense against air attack are startled when a well informed student of air power makes the positive statement that "Modern technique gives us the necessary weapons and means of (air) defense. Provided there is the will to achieve an efficient defensive system there is no reason whatever why it cannot be done. In our opinion the '100 per cent retaliatory' doctrine *à la Douhet* is a thing of the past and therefore an extremely dangerous an unsatisfactory solution of the problem."

If the book were prepared by a theorist whose assertions were not the result of many years investigation and study, it might be dismissed without considered comment, but when the Royal Air Force Quarterly opens its pages to the discussion it will command the attention of all who are trying to determine how soon the defense from air attack will catch up with the offensive, as has been done in many other forms of warfare.

With this challenge in the mind of the reader, he looks on each page for evidence to support the initial claims. It is, however, difficult to find the necessary substantiation. All will admit that anti-aircraft artillery has become more accurate and has raised the ceiling of attack to above 20,000 feet. The balloon aprons which it is claimed can reach 33,000 feet offer only limited defense which is, admittedly, as strong psychologically as it is physically. But when a summation is reached it all comes back to airplane against airplane and when this stage is reached, anti-aircraft must withhold its fire and listening apparatus is almost useless.

The book stresses the need for highly specialized types of airplanes for each different mission. Its examination of this field is excellent and, by itself, makes the book worth careful study. Whatever may be the distinguished officer's opinion he does not present convincing arguments or facts to lead the reader to believe that the best form of air defense still is not "retaliatory" or General Ashmore's "bomb-the-other-fellow" doctrine.

I Live Again, by ARTHUR ROWAN; Robert Hale, Ltd. London, 1938; 288 pages,

The background of many Royal Air Force officers is given in this biography. The author started his military career in the intelligence service and his experiences in India where he investigated the mystery of Indian magic gives an interesting prelude to his experiences with the R.A.F. in Turkey, Egypt, and Transjordan. His life as a prisoner in Bulgaria during the War, was none too pleasant. It is an informative story of the life of a British officer whose aim in life was always to go from the known to the unknown.